CONTRACT NUMBER NAS8-21155

SAFE OPERATING AREA DETERMINATION FOR PREVENTION OF SECOND BREAKDOWN

Performed for

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

By

THE BENDIX CORPORATION
THE BENDIX SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

THE BENDIX CORPORATION
BENDIX SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

TABLE OF CONTENTS

FOREWORD

SAFE OPERATING AREA (SOAR)

The Bendix SOAR principle is a method of specifying the Safe Operating Area for a transistor in a given application. SOAR defines the region which encloses all of the points representing simultaneous values of the collector current and the collector-to-emitter voltage which a transistor can safely handle under specified conditions of base current, time, junction temperature and average power dissipation. With transistors specified under the Bendix SOAR technique, second breakdown is virtually eliminated.

This report characterizes the Safe Operating Area of specific power transistors. The use of these Safe Operating Areas by designers will help avoid transistor second breakdown through design and quality considerations.

1.0 INTRODUCTION

The purpose of this contract was to determine the true dynamic characteristics, Safe Operating Area (SOAR), of selected power transistors used in critical space applications.

Testing to determine device parameters was made in accordance with JEDEC "Suggested Standard 65" and similiar to MIL-STD-750A. Reference to the aforementioned documents is made, wher(applicable, in the specification section of this Final Report.

Copies of the JEDEC "Suggested Standard 65" are available from:

Electronic Industries Association
2001 Eye Street, N.W.
Washington, D.C. 20006

The MIL-STD-750A document may be obtained from:

Commanding Officer
Naval Publications & Forms Center
5801 Tabor Avenue
Philadelphia, Pennsylvania 19120

2.0 CONCLUSIONS

The specifications and SOAR curves generated as a result of this Contract verifies the actual power handling capability for each type of transistor. This information will serve to:

1. Provide valid derating information to establish necessary safety margins;
2. Provide guidelines for circuit analysis;
3. Provide documented Reliability Data;
4. Provide a means to improve the overall quality of devices now used by MSFC.

The individual reports contain a detailed analysis of Safe Operating Area for devices not previously characterized for SOAR. Highlights from each device are summarized here as a guide to design personnel.

2N1486 Manufacturer A. Suggest change of spec. (Θ_{J-C} = 3 ^{o}C/W) to extend DC power rating. 33W at T_C = 100^{o}C provides safety margin for continuous operation. High energy device ideal for switching inductive loads.

2N1724 Manufacturer B. Device can sustain the rated power for all operating conditions.

2N1016D Manufacturer C. Device is capable of handling the manufacturers power rating.

2N1514 Manufacturer H. Marginal h_{FE} at 6A. Review circuits.

2N2102 Manufacturers D & J. Composite SOAR curves indicate that devices may vary from lot to lot by different manufacturers.

2N2034A Manufacturer E. Good energy dissipating capability.

2N2126 Manufacturer C. I_{CEO} should be part of specification to insure forward biased condition at high V_{CE} and low collector current.

2N657A Manufacturer E. A small device, heats up quickly causing failure at lower than published parameters.

2N697 Manufacturers G & E. Composite SOAR curves indicates a specification review of manufacturers E's device.

2N2880 Manufacturer H. Suggest continuous maximum DC rating be reduced from 5A to 3A. (I_E = 5.5A discolors leads.)

The following devices have recently been registered by Bendix and are not specifically covered by this Contract, however the results and data are included without charge, as additional information for NASA personnel. The format used in the presentation of this data was recently developed for the registration of transistor specifications.

SOAR Characteristics:

	T_{STG} max	min	T_J	V_{CEX}	V_{EBO}	V_{CBO}	I_C	P_T
2N5559	+200	-65°C	200°C	100V	7V	150V	10A	100W
2N5560	+200	-65°C	200°C	120V	8V	175V	30A	150W

The information obtained by this contract provides invaluable assistance to all concerned with the application, selection, performance, and most important, reliability of semiconductor devices in critical NASA systems.

The effect of SOAR evaluation is far-reaching, and should be a mandatory requirement for all power semiconductors being used by NASA in its Aeronautical and Space programs.

The Bendix Semiconductor Division hereby proposes that NASA continue this program with Bendix to further assist NASA in achieving the highest levels of Reliability in their programs.

Silicon Power Transistor

Type 2N1486

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer A --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

Contract No. NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item		Test Methods and Test Conditions
1.0.0	General Description	
1.1.0	Type -- NPN	
1.2.0	Material -- Silicon	
2.0.0	Mechanical Data	
2.1.0	Outline -- TO-8	
2.2.0	Terminal Designation 1 -- Emitter 2 -- Base 3 -- Collector case -- Collector	
3.0.0	Maximum Ratings	
3.1.0	Temperature	
3.1.1	$T_{STG(max)} = +200^{\circ}C$ $T_{STG(min)} = -65^{\circ}C$	JS-6-T1.2 JS-6-T1.1
3.1.2	$T_J = 200^{\circ}C$	JS-6-T2 $T_C = 100^{\circ}C$, $V_{CB} = 55V$, $P_T = 14.3W$
3.2.0	Voltage	
3.2.1	$V_{CBO} = 100V$	JS-6-T3 or MIL-STD-750, method 3001.1
3.2.2	$V_{EBO} = 12V$	JS-6-T4 or MIL-STD-750A method 3026.1
3.2.3	$V_{CEX} = 100V$	JS-6-T5-2.1 $I_C = 3.0A$, $V_{CC} = 100V$, $R_L = 33\Omega$, $L = 1mH$*, CR -- 1N1204, $V_{BB1} = 12V$, $R_{BB1} = 10\Omega$, $V_{BB2} = 3V$, $R_{BB2} = 10\Omega$ Duty Cycle = 2%, $t_p = 1.65$ ms. *Miller No. 7871 in series with Miller No. 7825-3
3.3.0	Current	
3.3.1	$I_C = 3A$	JS-6-T6, $I_B = 300mA$, $T_C = 25^{\circ}C$

Item		Test Methods and Test Conditions
3.3.2		JS-6-T8
		$T_C = 25^oC$
3.3.3	$I_C = -3.5A$	JS-6-T10
		$I_B = 500mA$, $T_C = 25^oC$
3.4.0	Power	
3.4.1	$P_T = 14.3W$	JS-6-T12
		$T_C = 100^oC$, $V_{CB} = 55V$, $I_C = .26A$
		Derating Factor - .143 $W/^oC$
3.4.2	$P_{TM} = I_C\ V_{CC} = 150W$	JS-6-T13
		$T_C = 100^oC$, $V_{CC} = 50V$, $V_{BB} = 3V$
		$R_{BB} = 10\Omega$, $I_C \doteq 3A$, Pulse Width = 5ms,
		Duty Cycle = 5%, $t_r \leq 50\mu s$,
		$t_f \leq 50\mu s$
3.5.0	Maximum Operating Condition	
3.5.1	Forward Biased Continuous DC-SOAR	JS-6-T12 (See Figure 1)
		Test Point (See 3.4.1)
3.5.2	Pulsed Forward Biased SOAR	JS-6-T-14 (See Figure 2)
		Test Points:
		$T_C = 100^oC$, $V_{BB} = 3V$, $R_{BB} = 10\Omega$,
		$t_r \leq 50\mu s$, $t_f \leq 50us$, $I_C = 3A$,
		Duty Cycle $\leq$ 1%, $R_S = 0.1\Omega$
		1. For $t_p = 50ms$: $V_{CC} = 10V$
		2. For $t_p = 20ms$: $V_{CC} = 25V$

Item		Test Methods and Test Conditions
3.5.2	Pulsed Biased (Cont'd) Continuous DC SOAR	3. For t_p = 10ms, V_{CC} = 40V 4. For t_p = 5ms, V_{CC} = 50V
3.6.0	SOAR Switching between Saturation and Cutoff	
3.6.1	Resistive Load	<u>JS-6-T5-2.1</u> with L = 0 and CR disconnected. See (Figure 3) <u>Test Points</u>: R_{BB1} = 10Ω, R_{BB2} = 10Ω, V_{BB1} = 12V, V_{BB2} = 3V, T_C = 100°C, $t_f \leq 50\mu s$ (Coll. Current); $t_r \leq 50\mu s$ (Coll. Current), R_S = 0.1Ω, I_C = 3A, V_{CC} = 100V
3.6.2	Clamped Inductive Load	<u>JS-6-T5.1</u> (See Figure 4) Test Points: (See 3.2.3)
3.6.3	Unclamped Inductive Load	<u>JS-6-T5.1</u> and CR disconnected (See Figure 5) <u>Test Points</u>: 1. V_{BB1} = 12V, L = 20mH* R_{BB1} = 10Ω, R_L = 4.1Ω V_{BB2} = 3V, V_{CC} = 12.5V R_{BB2} = 10Ω, f = 10Hz R_S = 0.1Ω, d = 15%. *Series Stancor C-2688

Item		Test Methods and Test Conditions
3.7.0	Shorted Class B SOAR	(See Figure 6)
		Test Points:
		$I_{C(peak)} = .75A$, $V_{CC} = 55V$, $R_S = 0.1\Omega$
		$R_{BB1} = 10\Omega$, $R_{BB2} = 10\Omega$, $f = 20Hz$,
		$T_C = 100^oC$
4.0.0	Electrical Characteristics	
	Maximum Limits unless other otherwise noted.	
	Technique:	
	DC = continuous operation	
	C.T. = Curve Tracer	
	P = 300µs Pulse, 2% Duty Cycle	
4.1.0	Static	
4.1.1	$I_{CEV} = 10\mu A$	$V_{CEV} = 100V$, $V_{EB} = 1.5V$, Technique = C.T.
4.1.2	$I_{CBO} = 15\mu A$	$V_{CB} = 30V$, Technique = C.T.
4.1.3	$I_{CBO} = 750\mu A$	$V_{CB} = 30V$, $T_C = 150^oC$, Technique = C.T.
4.1.4	$I_{EBO} = 15\mu A$	$V_{EB} = 12V$, technique = C.T.
4.1.5	$I_{CEO} = 50\mu A$	$V_{CEO} = 50V$, technique = C.T.
4.1.6	$V_{CEO} = 55V$ min.	$I_{CEO} = 100mA$, technique = C.T.
4.1.7	$V_{CEV} = 100V$	$I_C = 100mA$, $V_{EB} = 1.5V$, technique = C.T.
4.1.8	$h_{FE} = 35$ min.	$V_{CE} = 4V$, $I_C = 750mA$, technique = C.T.
	$h_{FE} = 100$ max.	
4.1.9	$V_{CE[SAT]} = .75V$	$I_C = 0.75A$, $I_B = .04A$, technique = C.T.

Item		Test Methods and Test Conditions
4.1.10	$V_{CE[SAT]} = 2.5V$	$I_C = 3A$, $I_B = 300mA$, technique = C.T.
4.1.11	$V_{BE[SAT]} = 3.0V$	$I_C = 3A$, $I_B = 300mA$, technique = C.T.
4.1.12	$V_{BE} = 2.5V$	$I_C = 750mA$, $V_{CE} = 4V$, technique = C.T.
4.2.0	Dynamic	
4.2.1	$f_{hfb} = 1MHz$ min.	$I_C = 5mA$, $V_{CE} = 28V$
	$f_{hfb} = 10$ MHz max.	
4.2.2	$C_{obo} = 175pF$	$V_{CB} = 40V$, MIL-STD -750 method 3236
5.0.0	Thermal Characteristics	
5.1.0	$\tau_J = 40mS$ min.	$I_C = 1A$, $V_{CE} = 10V$, $T_C = 25^{\circ}C$ MIL-STD -750 method 3146.1
5.2.0	$\theta_{J-C} = 7.0\ ^{\circ}C/W$	$I_C = 1A$, $V_{CE} = 10V$, $T_C = 25^{\circ}C$ MIL-STD -750 method 3136
5.3.0	$\theta_{J-A} = 100\ ^{\circ}C/W$	$I_C = .5A$, $V_{CE} = 3.5V$, MIL-STD -750 method 3151

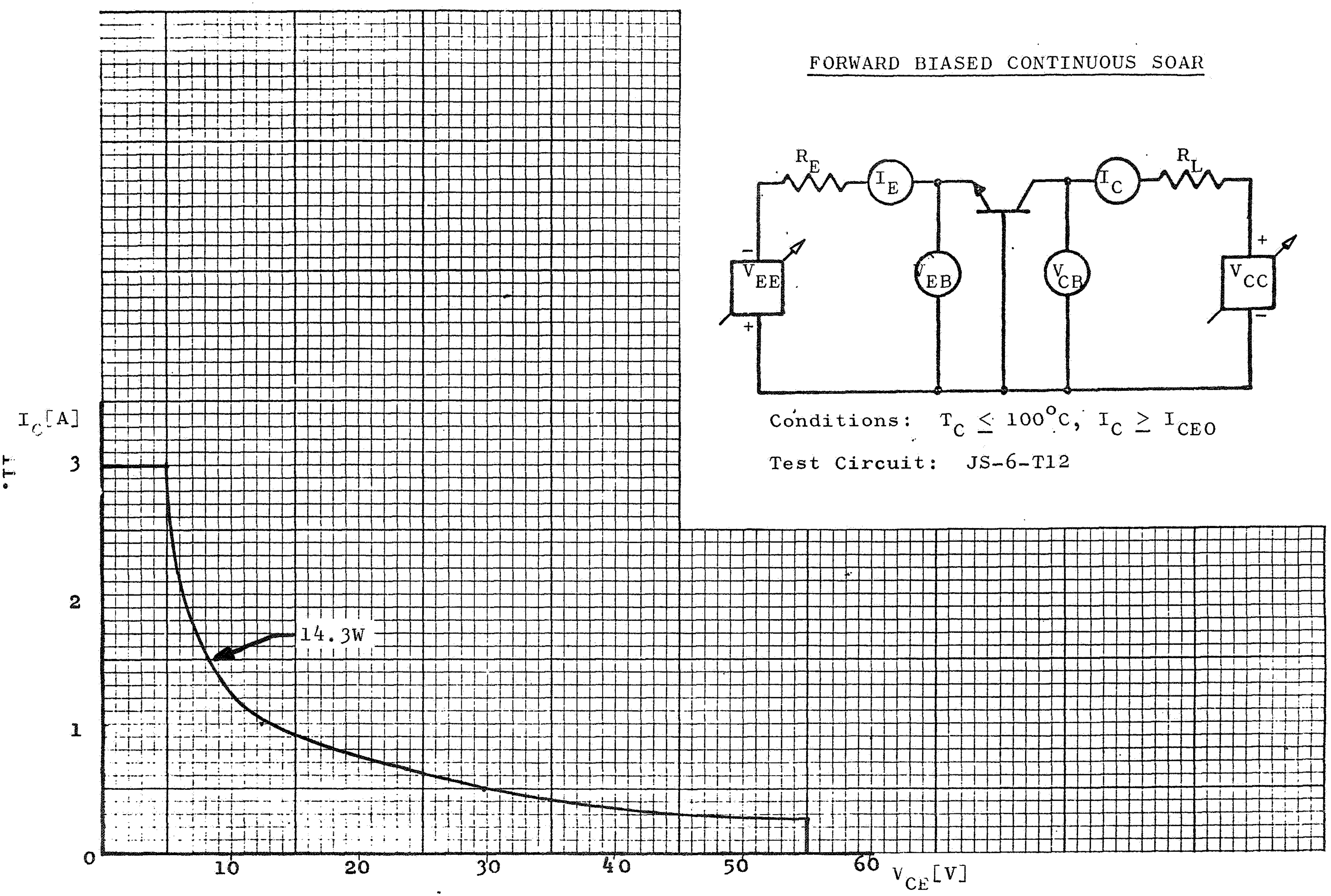

FORWARD BIASED CONTINUOUS SOAR
R_E
I_E
V_{EB}
V_{CB}
I_C
R_L
V_{EE}
V_{CC}
Conditions: $T_C \leq 100^oC$, $I_C \geq I_{CEO}$
Test Circuit: JS-6-T12
$I_C[A]$
3
2
1
0
10
20
30
40
50
60
$V_{CE}[V]$
14.3W

Figure 1

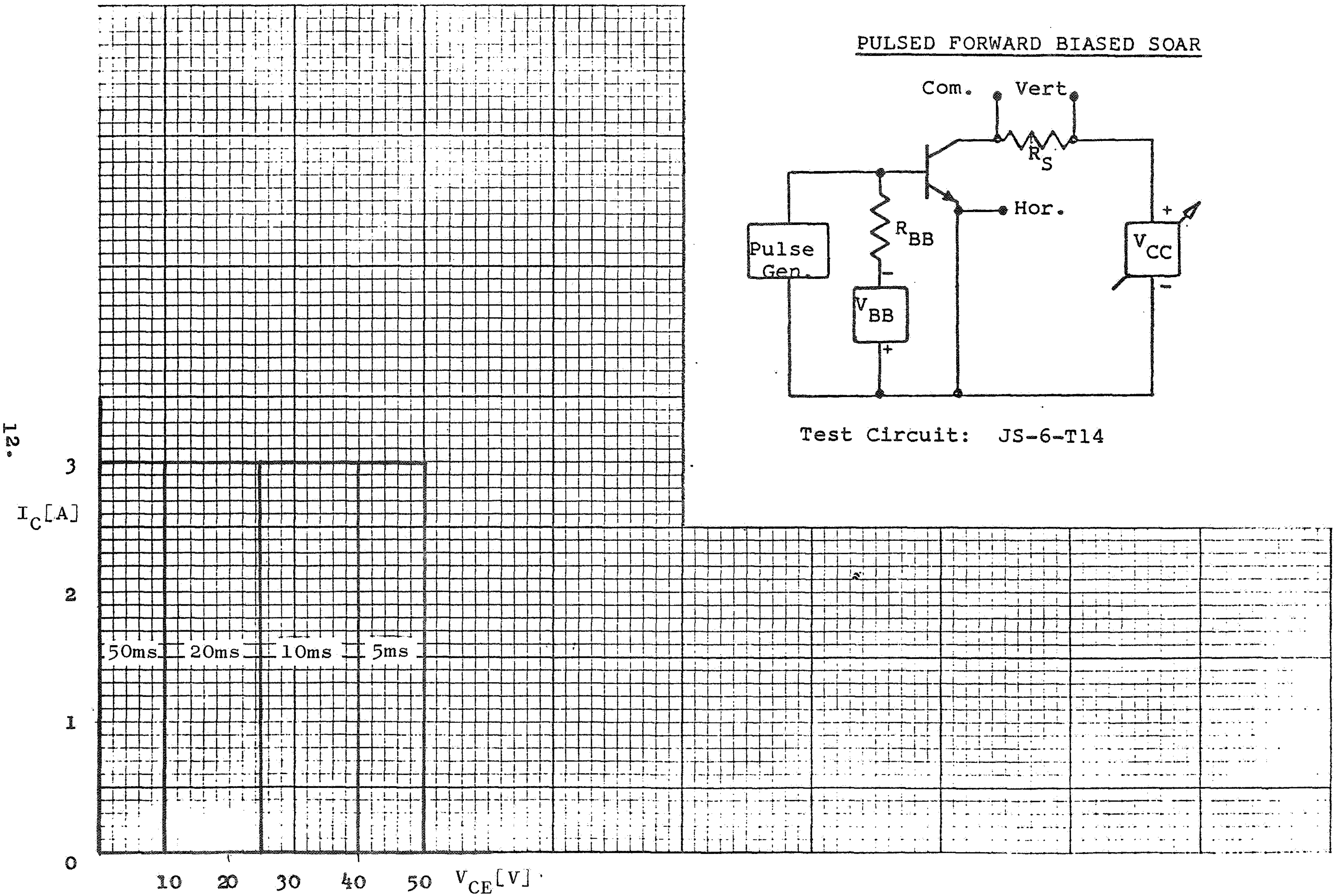

PULSED FORWARD BIASED SOAR
Com.
Vert.
R_S
Hor.
R_{BB}
Pulse Gen.
V_{BB}
V_{CC}
Test Circuit: JS-6-T14
3
I_C[A]
2
1
0
50ms
20ms
10ms
5ms
10
20
30
40
50
V_{CE}[V]

Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

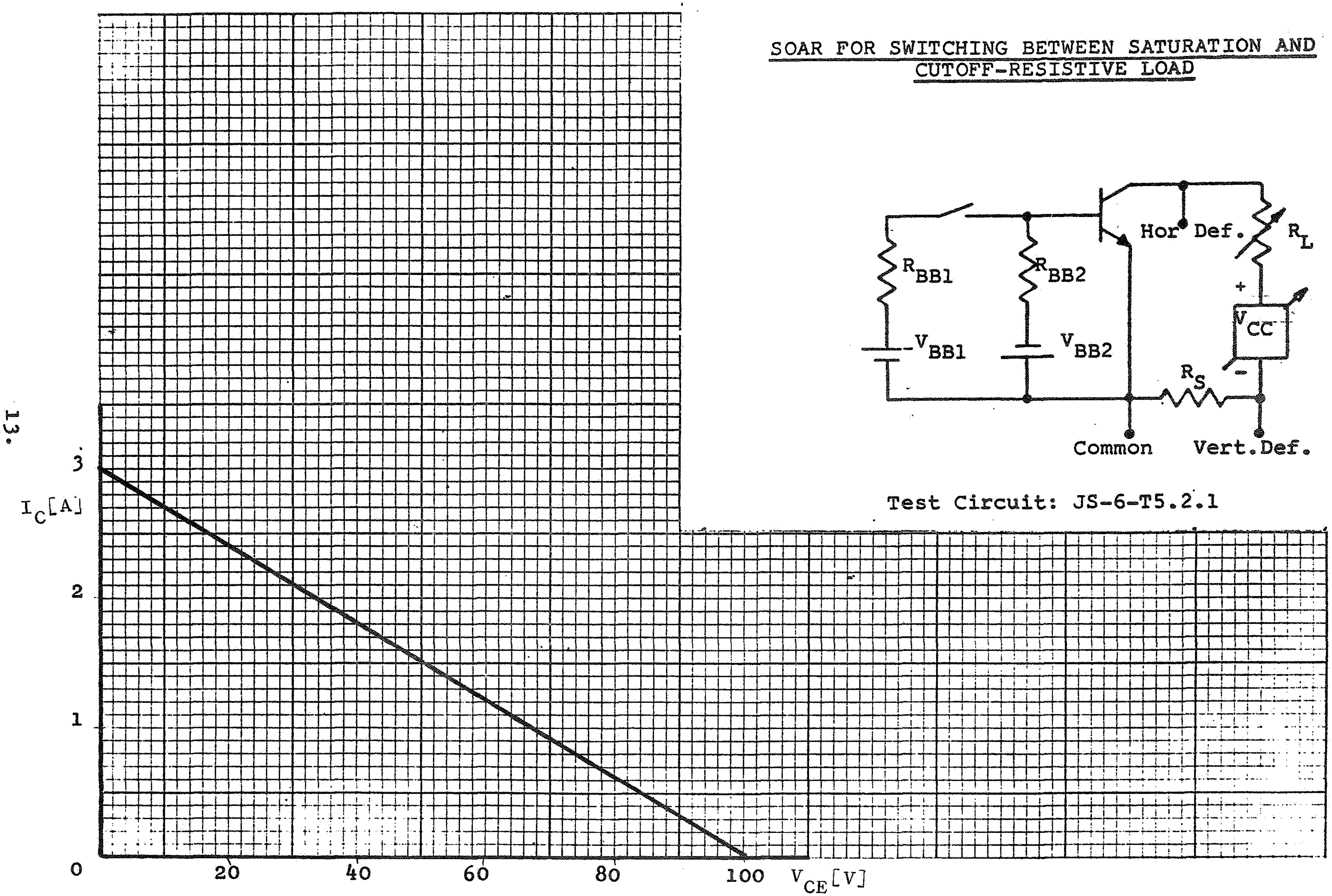


Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD

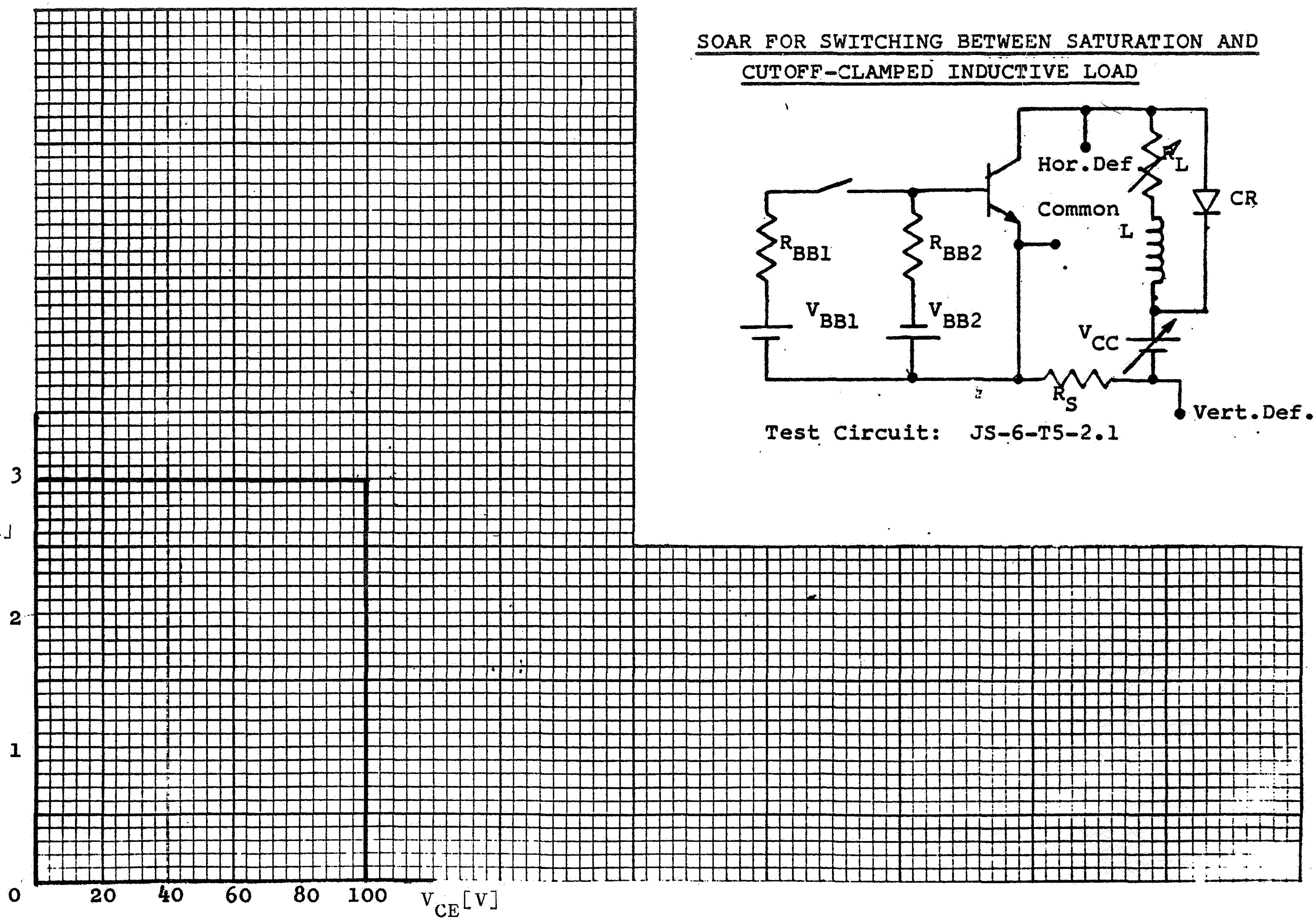
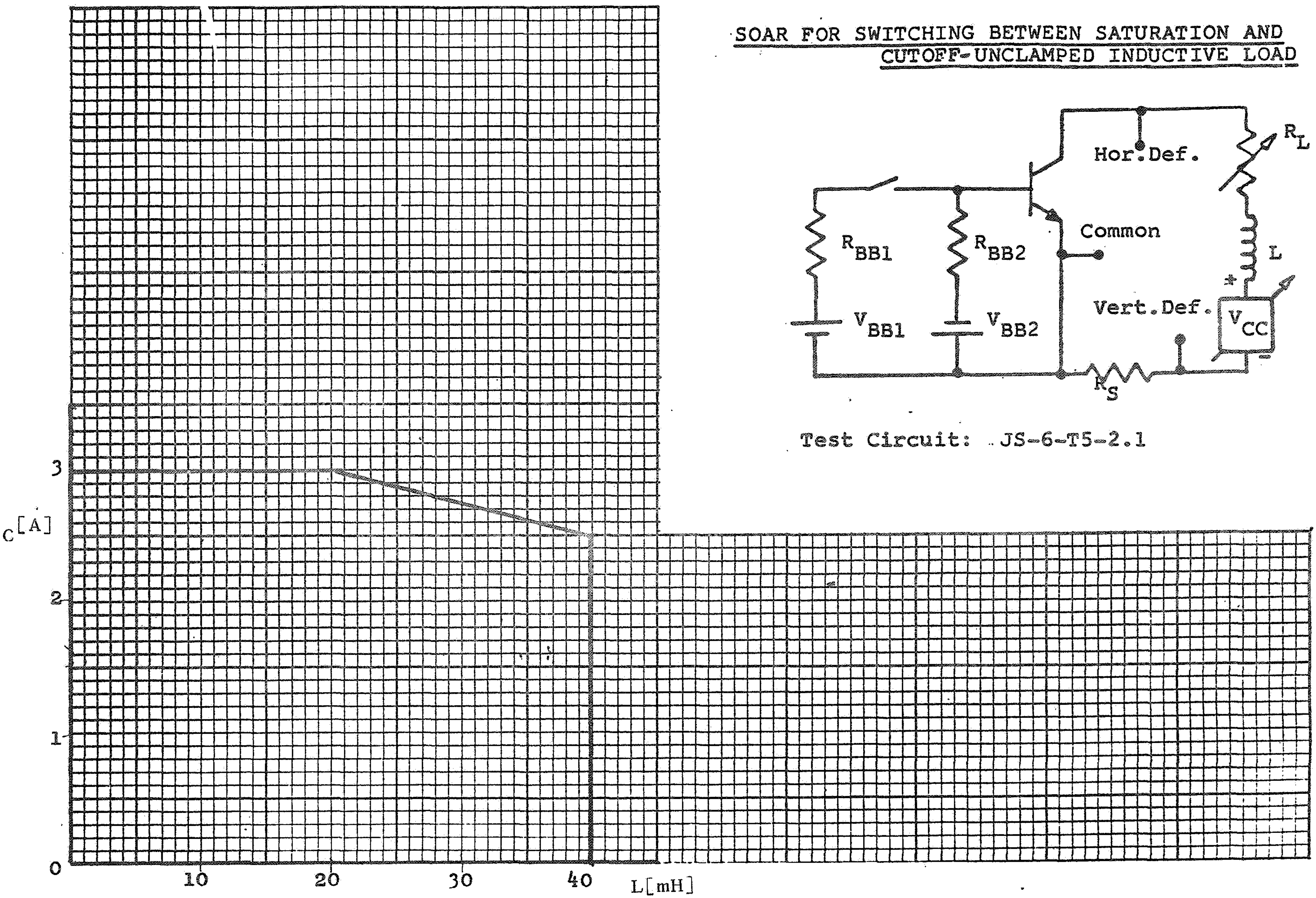


Figure 4

15.

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

Figure 5

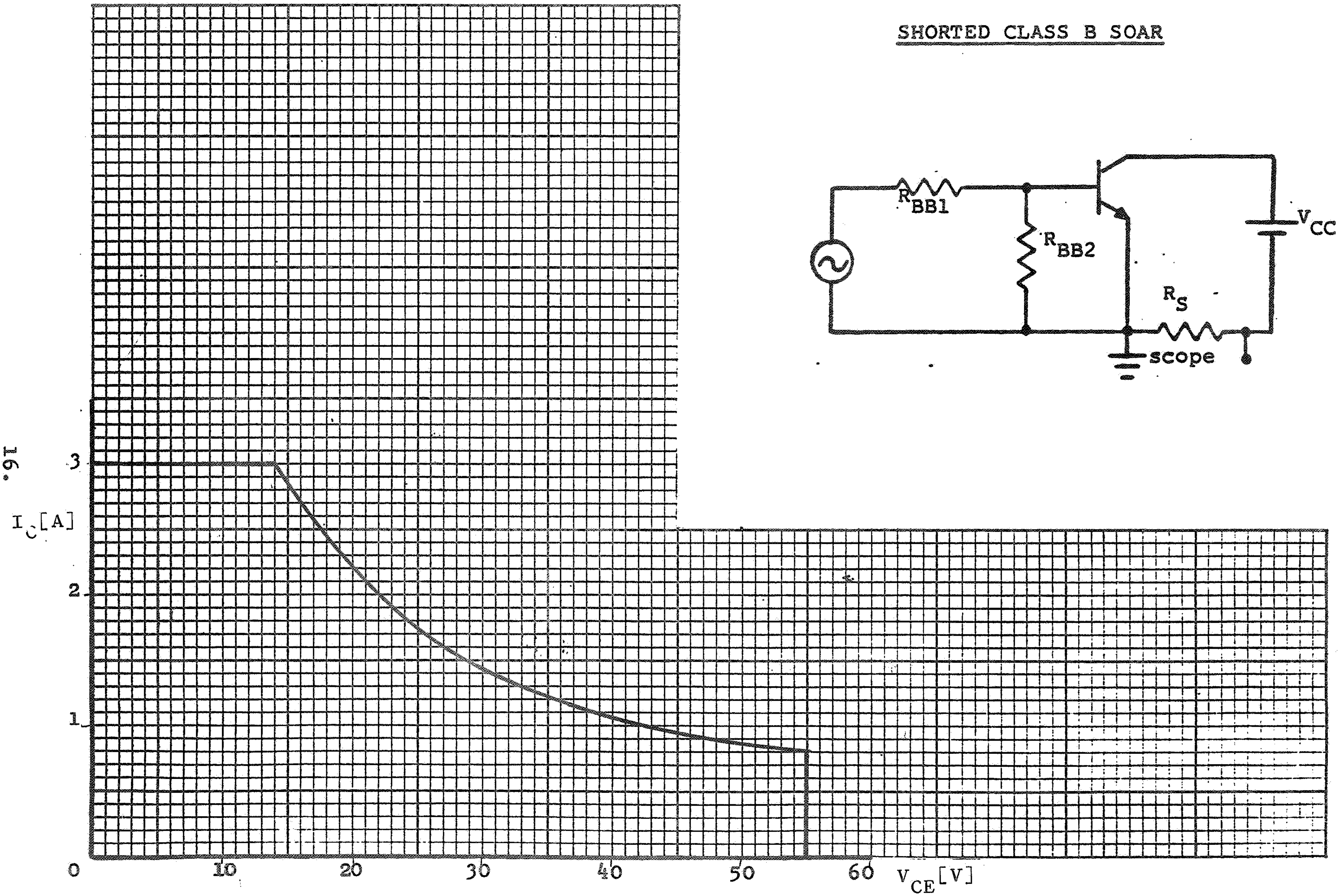

SHORTED CLASS B SOAR
R_{BB1}
R_{BB2}
V_{CC}
R_S
scope
I_C[A]
3
2
1
0
10
20
30
40
50
60
V_{CE}[V]

Figure 6

SILICON POWER TRANSISTOR

< Type 2N1724 >

SAFE OPERATING AREA DETERMINATION FOR PREVENTION OF SECOND BREAKDOWN

-- Manufacturer B --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item		Test Method and Test Conditions
1.0.0	General Description	
1.1.0	Type -- NPN	
1.2.0	Material -- Silicon	
2.0.0	Mechanical Data	
2.1.0	Outline -- TO-61	
2.2.0	Terminal Designation 1 -- Emitter 2 -- Base 3 -- Collector case -- Collector	
2.2.1	Maximum Stud Torque -- 30 in. lb.	
3.0.0	Maximum Ratings	
3.1.0	Temperature	
3.1.1	$T_{STG(max)} = +200^{o}C$	JS-6-T1.1 (JEDEC Suggested Standard: "Test Procedures for Verifications of Maximum Ratings")
	$T_{STG(min)} = -65^{o}C$	JS-6-T1.2
3.1.2	$T_{J(max)} = +175^{o}C$	JS-6-T2 $T_C = 100^{o}C$, $V_{CB} = 10V$, $I_C = 5A$
3.1.3	$T(Lead) = 230^{o}C$	Distance from case = 1/4 in. Time = 10s
3.2.0	Voltage	$T_C = 25^{o}C$
3.2.1	$V_{CBO} = 120V$	JS-6-T3 or MIL-STD-750A Method 3001.1
3.2.2	$V_{EBO} = 10V$	JS-6-T4 or MIL-STD-750A Method 3026.1

Item		Test Methods and Test Conditions
3.2.3	V_{CEV} = 80V	JS-6-T5-2.1 I_C (V_{CE} = V_{CEX}) = 7.5A V_{CC} = 80V, R_L = 10.3Ω, L = 1mH, (Miller #7870), CR = 1N1204, V_{BB1} = 15V, R_{BB1} = 5Ω, V_{BB2} = 5V, R_{BB2} = 10Ω, Pulse width = 10ms, Duty Cycle = 10%, R_S = 0.1Ω
3.3.0	Current	
3.3.1	I_C = 5A	JS-6-T6 I_B = 1A, T_C = 25°C
3.3.2	I_{CM} = 7.5A	JS-6-T7 T_C = 25°C, R_S = 0.1Ω, V_{BB} = 5V, R_{BB} = 10Ω Pulse Amplitude = 5.3V, R source = 1Ω Pulse Width = 20ms, Duty Cycle = 20% $t_r \leq 50\mu s$, $t_f \leq 50\mu s$
3.3.3	I_B = 2A	JS-6-T8 T_C = 25°C
3.3.4	I_E = 6A	JS-6-T10 I_B = 1A, T_C = 25°C
3.4.0	Power	
3.4.1	P_T = 50W	JS-6-T12 T_C = 100°C, V_{CB} = 80V, I_C = 625mA Derating factor = 0.667W/°C

Item		Test Methods and Test Conditions
3.4.2	$P_{TM} = 600W$	JS-6-T13 $T_C = 100^oC$, $V_{CC} = 80V$, $I_C = 7.5A$ $V_{BB} = 5V$, $R_{BB} = 10\Omega$, Pulse Width = 1ms, Duty Cycle = 2%, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$
3.5.0	Maximum Operating Conditions	
3.5.1	Forward Biased Continuous DC-SOAR	JS-6-T12 (See Figure 1) Test Point: (See 3.4.1)
3.5.2	Pulsed Forward Biased SOAR	JS-6-T14 (See Figure 2) Test Point: $T_C = 100^oC$, $V_{BB} = 5V$, $R_{BB} = 10\Omega$, $I_C = 7.5A$, $R_S = 0.1\Omega$, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$, Duty Cycle $\leq$ 5% 1. For t_p = 3ms: V_{CC} = 55V 2. For t_p = 2ms: V_{CC} = 65V 3. For t_p = 1ms: V_{CC} = 80V
3.6.0	SOAR Switching between Saturation and Cutoff	
3.6.1	Resistive Load	JS-6-T5-2.1 with L = 0 and CR Disconnected (See Figure 3) Test Points: $T_C = 100^oC$, Duty Cycle = 10%, Coll. Current, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$ $R_{BB1} = 5\Omega$, $R_{BB2} = 10\Omega$, $V_{BB1} = 15V$, $V_{BB2} = 5V$, $I_C = 7.5A$, $V_{CC} = 120V$, $R_L = 15.6\Omega$, $R_S = 0.1\Omega$

Item		Test Methods and Test Conditions
3.6.2	Clamped Inductive Load	JS-6-T5-2.1 (See Figure 4) Test Point: (See 3.2.3)
3.6.3	Unclamped Inductive Load	JS-6-T5-2.1 and CR disconnected (See Figure 5) Test Point: [1.] $R_{BB1} = 5\Omega$, $R_{BB2} = 10\Omega$, $V_{BB1} = 15V$, $V_{BB2} = 5V$, $L = 5mH$, 0.03Ω (Stancor #C-2689) $I_C = 7.5A$, $V_{CC} = 18V$, $R_L = 2\Omega$, $R_S = 0.1\Omega$, $d \leq 10\%$, $T_C = 25^oC$, $t_p = 10ms$ [2.] $R_{BB1} = 5\Omega$, $R_{BB2} = 10\Omega$, $V_{BB1} = 8V$, $V_{BB2} = 5V$, $L = 20mH$, 0.22Ω (two in series Stancor #C-2688) $I_C = 2.5A$, $V_{CC} = 13.5V$, $R_L = 5\Omega$, $R_S = 0.1\Omega$, $T_C = 25^oC$, $d \leq 10\%$, $t_p = 10ms$
3.7.0	Shorted Class B SOAR (See Figure 6)	Test Point: I_C peak $= 1.88A$, $V_{CC} = 80V$, $R_S = 0.1\Omega$, $R_{BB1} = 1\Omega$, $R_{BB2} = 10\Omega$, f=20Hz, $T_C = 100^oC$
4.0.0	Electrical Characteristics	$T_C = 25^oC$ (unless otherwise noted)

Maximum limits unless otherwise noted

Technique:

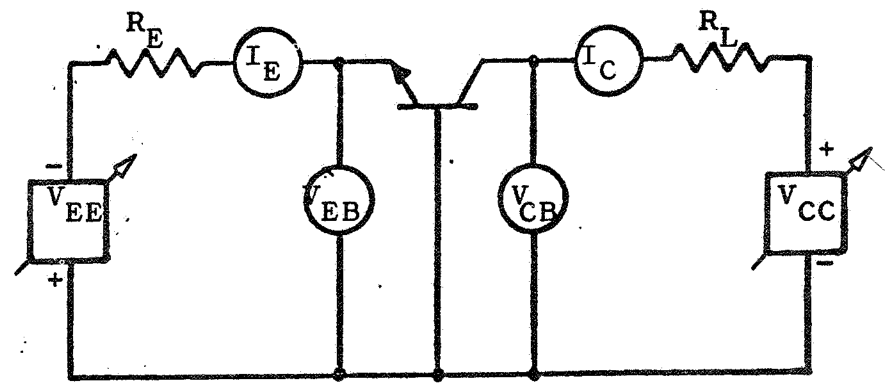
DC - Continuous Operation

C.T. - Curve Tracer

P - 300µs Pulse, 2% Duty Cycle

Item		Test Methods and Test Conditions
4.1.0	Static	
4.1.1	I_{CBO} = 0.5mA	V_{CB} = 3V Technique – C.T.
4.1.2	V_{EBF} = 10V	V_{CB} = 80V Technique – C.T.
4.1.3	I_{CES} = 1.0mA	V_{CE} = 60V Technique – C.T.
4.1.4	I_{CES} = 2.0mA	T_C = 150°C, V_{CE} = 60V Technique – C.T.
4.1.5	I_{CES} = 10mA	T_C = 150°C, V_{CE} = 120V Technique – C.T.
4.1.6	I_{CEO} = 10mA	T_C = 25°C, V_{CE} = 80V Technique – C.T.
4.1.7	I_{EBO} = 10mA	V_{EB} = 10V Technique – C.T.
4.1.8	V_{CEO} = 80V min.	I_C = 0.2A Technique – C.T.
4.1.9	h_{FE} = 20 min	V_{CE} = 15V, I_C = 0.1A Technique – C.T.
4.1.10	h_{FE} = 20 min, 90 max	V_{CE} = 15V, I_C = 2A Technique – P
4.1.11	h_{FE} = 10 min	V_{CE} = 2V, I_C = 5A Technique – P
4.1.12	$V_{CE(sat)}$ = 1V	I_C = 2A, I_B = 0.2A, Technique – C.T.
4.1.13	$V_{CE(sat)}$ = 2V	I_C = 7.5A, I_B = 1.5A Technique –P
4.1.14	$V_{BE(sat)}$ = 2V	I_C = 2A, I_B = 0.2A, Technique – C.T.
4.1.15	$V_{BE(sat)}$ = 2.5V	I_C = 7.5A, I_B = 1.5A Technique – P
4.2.0	Dynamic	
4.2.1	h_{fe} = 2.0 min = 10.0 max	V_{CE} = 15V, I_C = 0.5A, f = 5 MHz
4.2.2	C_{obo} = 550 pF max	V_{CB} = 15V, f = 1MHz
5.0.0	Thermal Characteristics	
5.1.0	τ_J min = 10ms	V_{CE} = 10V, I_C = 2A, T_C = 25°C, MIL-STD-750, Method 3146.1
5.2.0	θ_{JC} = 1.5 °C/W	V_{CE} = 10V, I_C = 2A, T_C = 25°C MIL-STD-750, Method 3136

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^{\circ}C$, $I_C \geq I_{CEO}$

Test Circuit: JS-6-T12

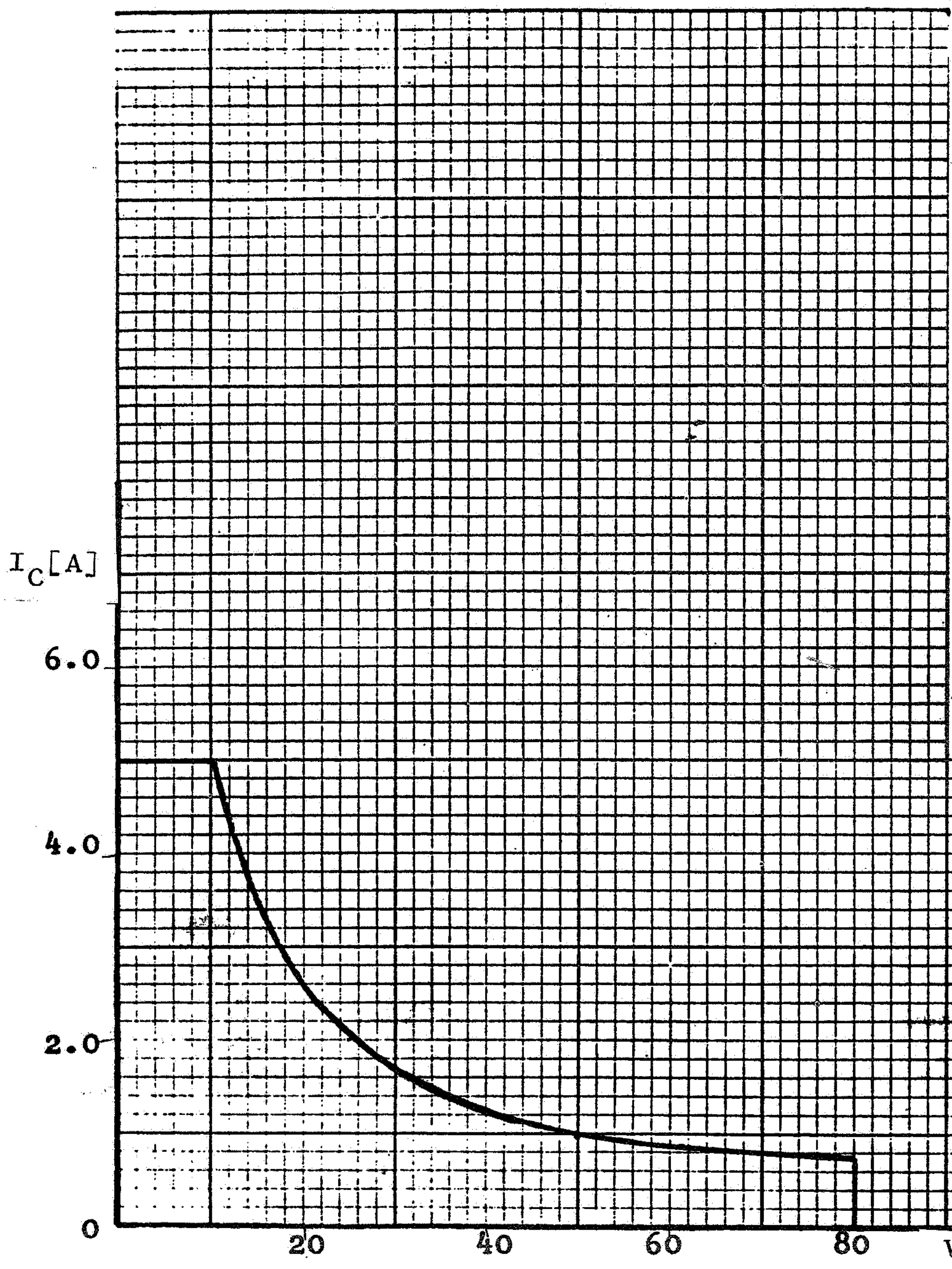


Figure 1

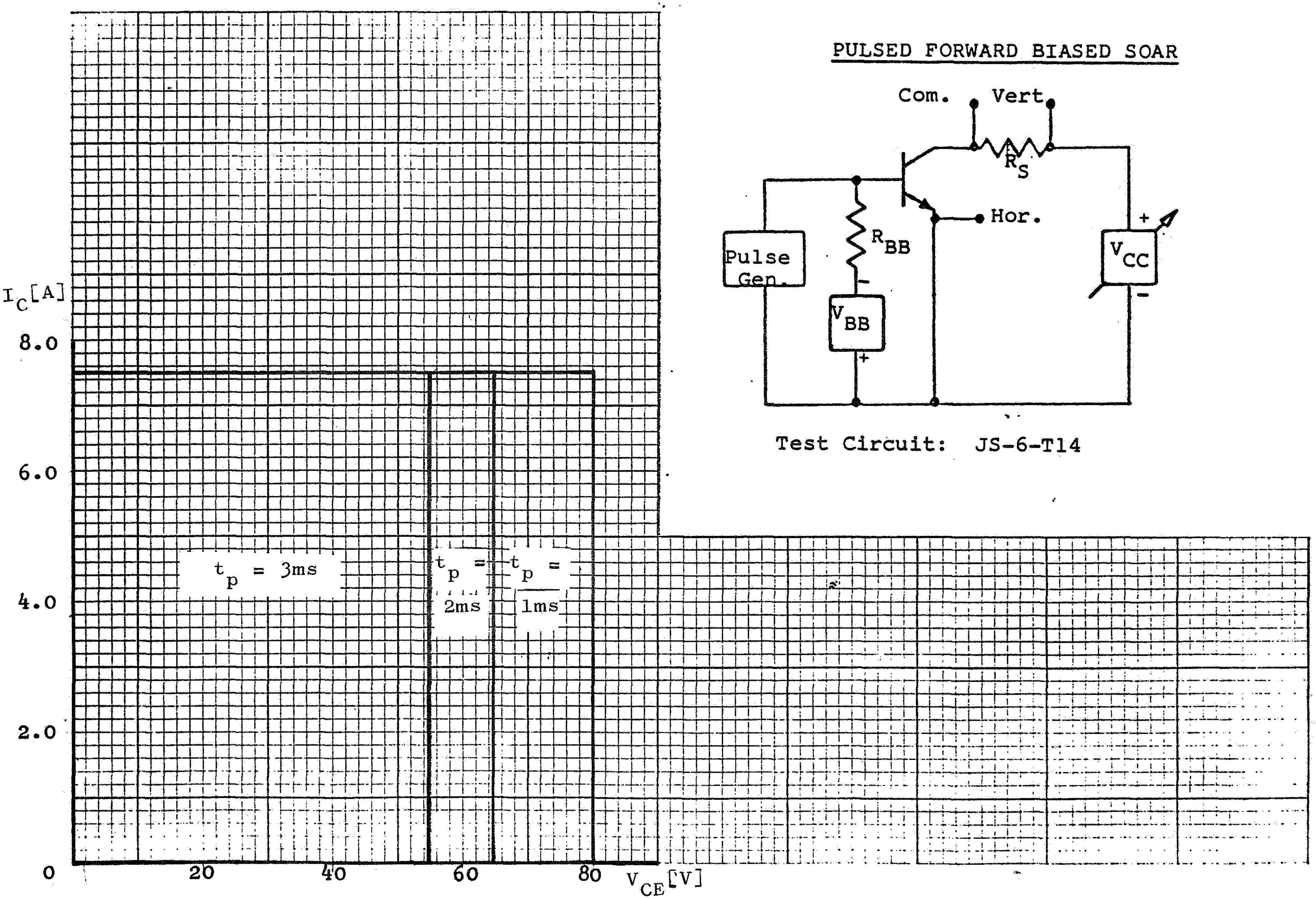

PULSED FORWARD BIASED SOAR
Com.
Vert.
R_S
Hor.
Pulse Gen.
R_{BB}
V_{BB}
V_{CC}
Test Circuit: JS-6-T14
I_C[A]
8.0
6.0
4.0
2.0
0
20
40
60
80
V_{CE}[V]
t_p = 3ms
t_p = 2ms
t_p = 1ms

Figure 2

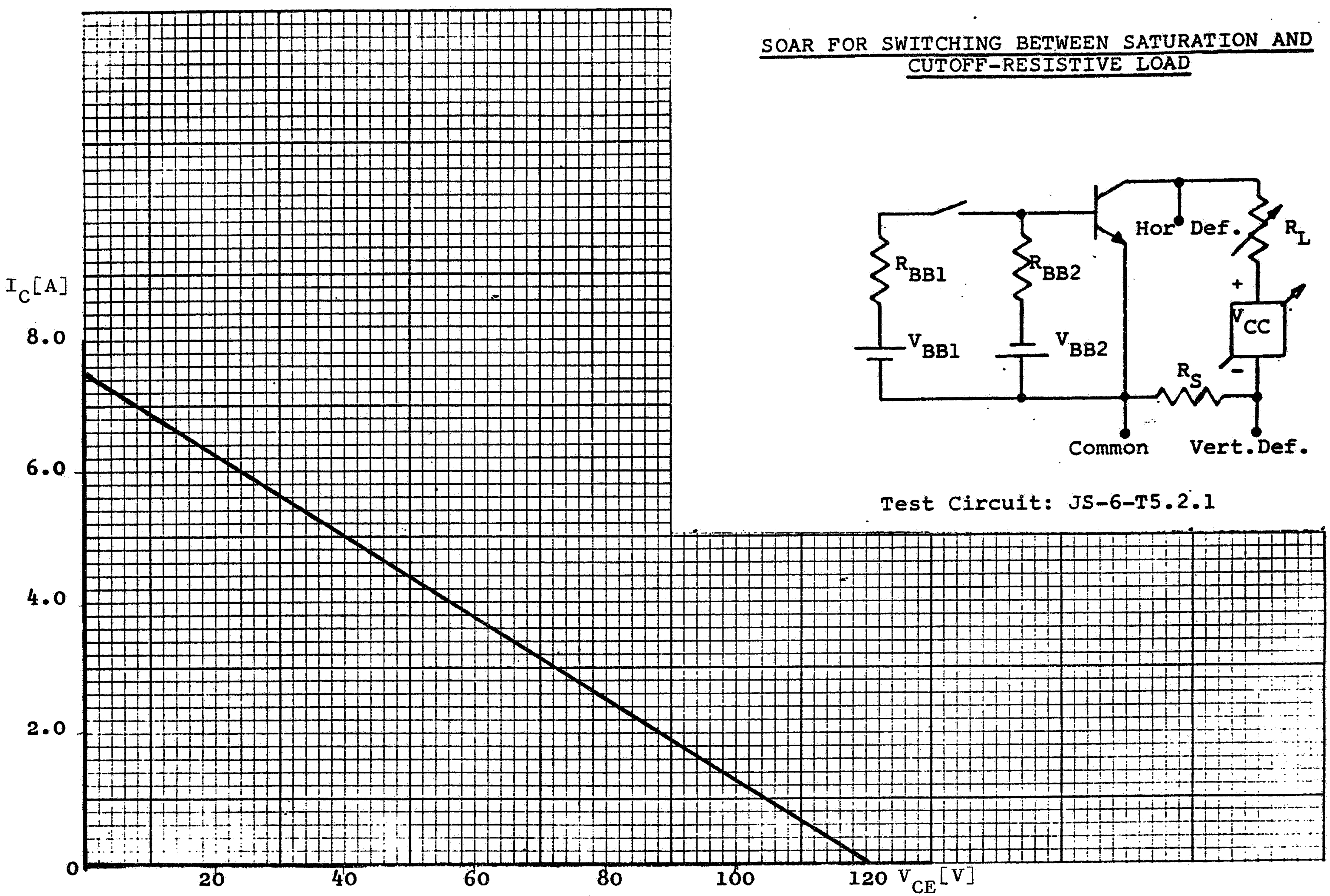
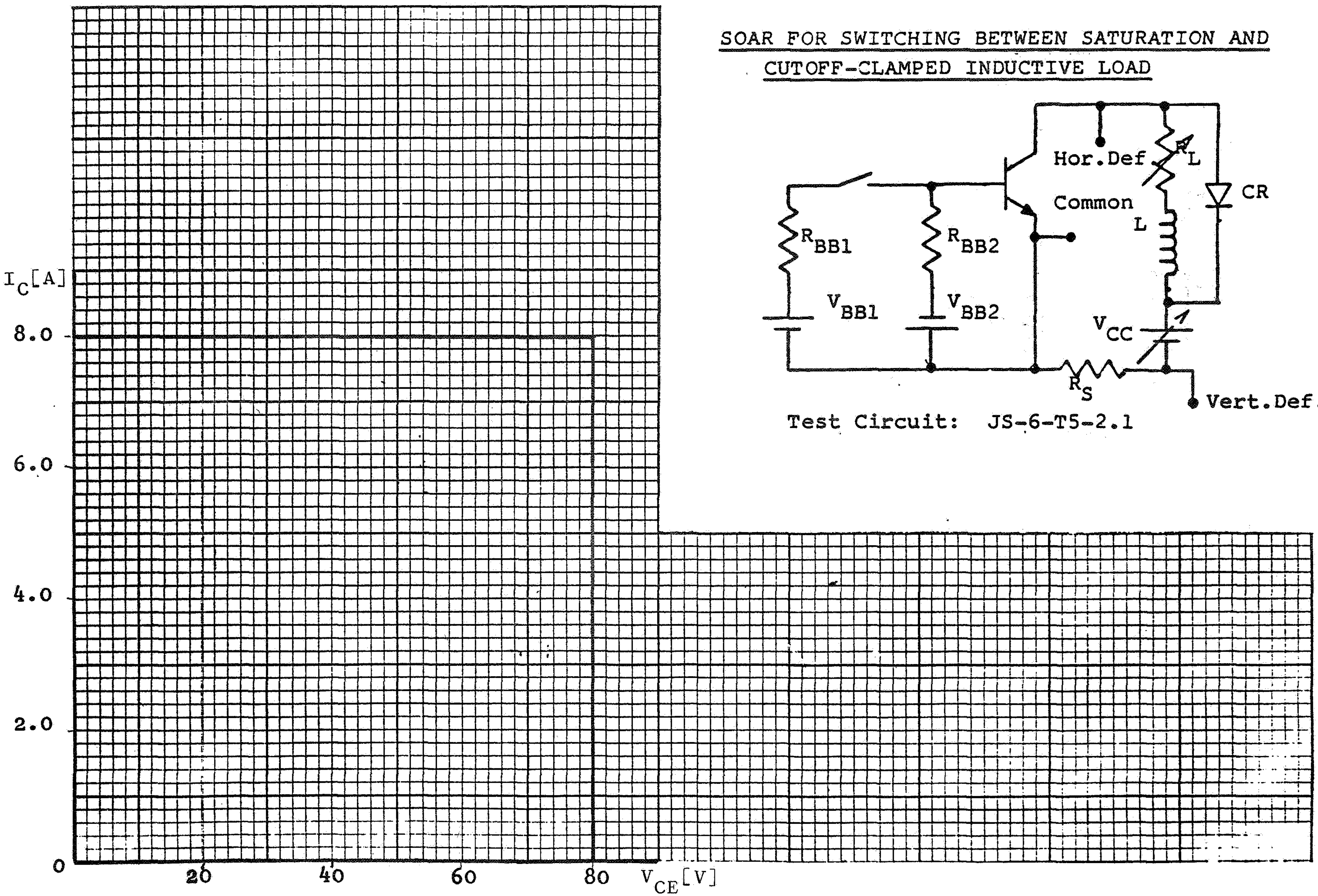

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-RESISTIVE LOAD
R_{BB1}
V_{BB1}
R_{BB2}
V_{BB2}
Hor Def.
R_L
+
V_{CC}
−
R_S
Common
Vert.Def.
Test Circuit: JS-6-T5.2.1
I_C[A]
8.0
6.0
4.0
2.0
0
20
40
60
80
100
120
V_{CE}[V]

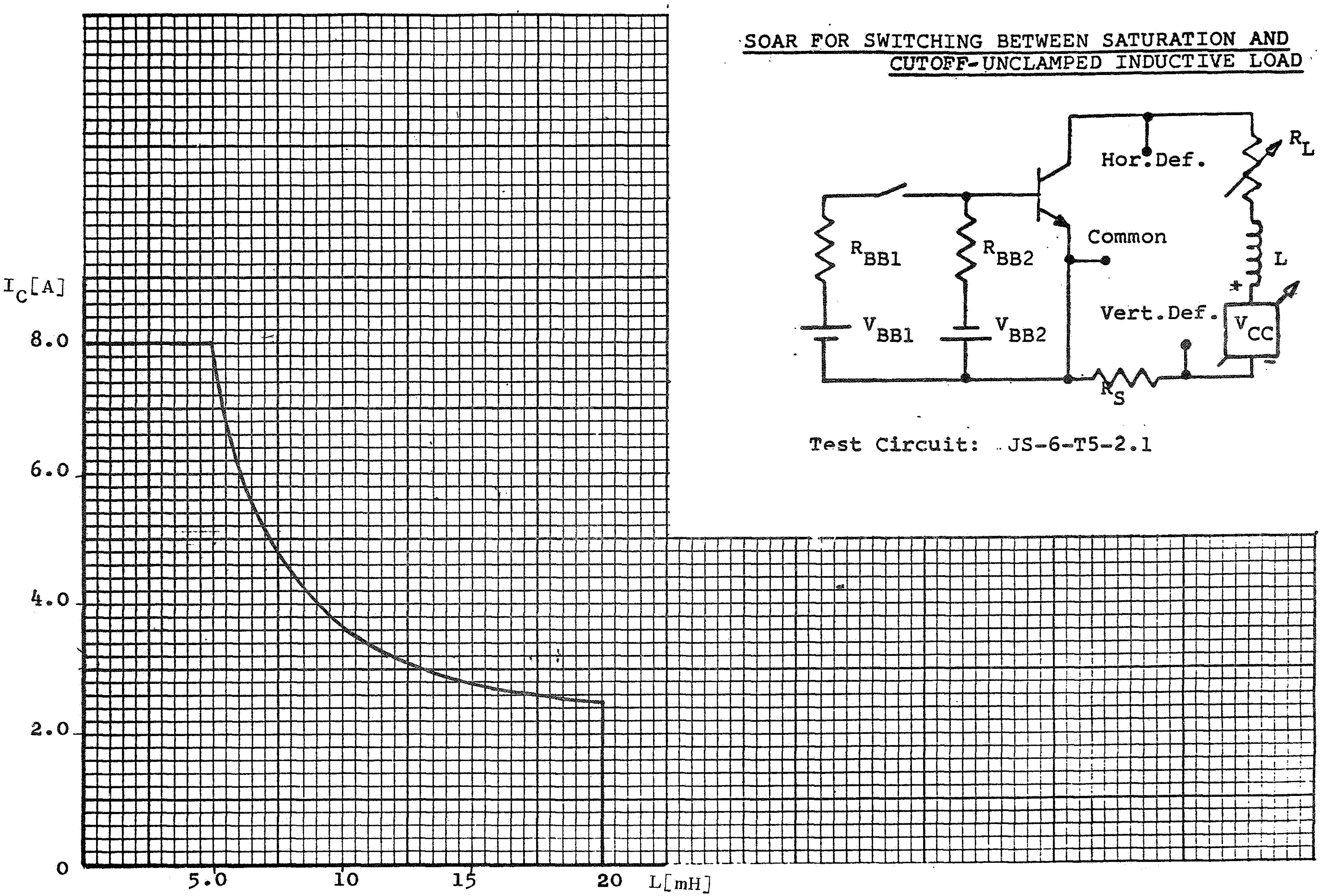
Figure 3



SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD

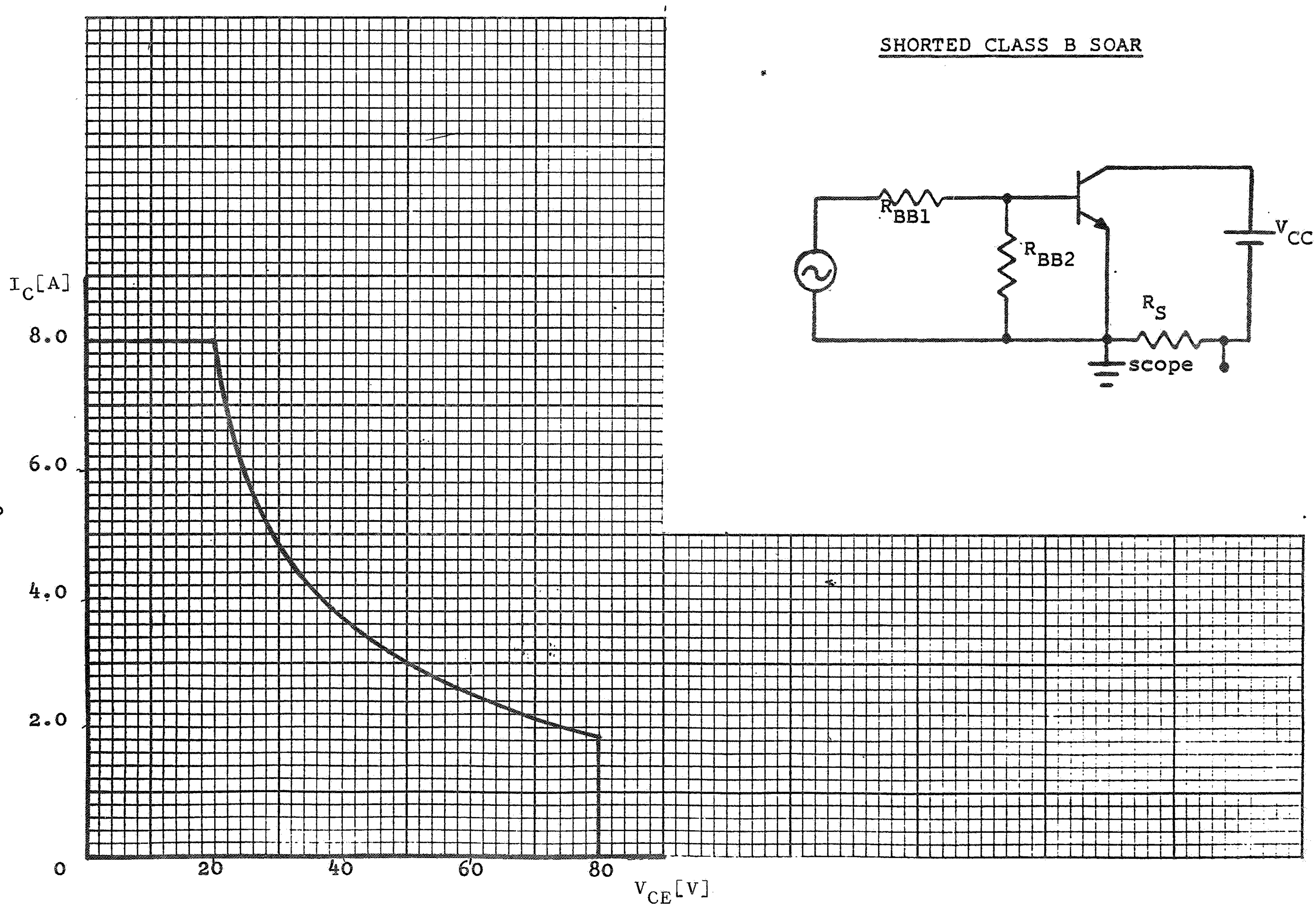
Test Circuit: JS-6-T5-2.1

Figure 4



SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-UNCLAMPED INDUCTIVE LOAD
R_L
Hor. Def.
Common
L
R_{BB1}
R_{BB2}
V_{BB1}
V_{BB2}
Vert. Def.
V_{CC}
+
−
R_S
Test Circuit: JS-6-T5-2.1
I_C[A]
8.0
6.0
4.0
2.0
0
5.0
10
15
20
L[mH]

Figure 5



SHORTED CLASS B SOAR
R_{BB1}
R_{BB2}
V_{CC}
R_S
scope
I_C[A]
8.0
6.0
4.0
2.0
0
20
40
60
80
V_{CE}[V]

Figure 6

SILICON POWER TRANSISTOR

< Type 2N1016D >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer C --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item		Test Methods and Test Conditions
1.0.0	General Description	
1.1.0	Type -- NPN	
1.2.0	Material -- Silicon	
2.0.0	Mechanical Data	
2.1.0	Outline -- TO-82	
2.2.0	Terminal Designation	
	1 -- Base	
	2 -- Emitter	
	3 -- Collector	
	Case -- Collector	
2.2.1	Maximum Stud Torque -- 50 in lbs.	
	Minimum Stud Torque -- 40 in lbs.	
3.0.0	Maximum Ratings	
3.1.0	Temperature	
3.1.1	$T_{STG(max)} = +150^{\circ}C$	JS-6-T1.1 (JEDEC Suggested Standard: "Test Procedures for Verifications of Maximum Ratings")
	$T_{STG(min)} = -65^{\circ}C$	JS-6-T1.2
3.1.2	$T_J = 150^{\circ}C$	JS-6-T2
		$T_C = 100^{\circ}C$, $V_{CB} = 100V$, $I_C = 0.71A$
3.1.3	$T(\text{Lead}) = 230^{\circ}C$	Distance from case = 1/4 in., Time = 10s
3.2.0	Voltage	
3.2.1	$V_{CBO} = 200V$	JS-6-T3 or MIL-STD-750A Method 3001.1
3.2.2	$V_{EBO} = 25V$	JS-6-T4 or MIL-STD-750A Method 3026.1
3.2.3	$V_{CEX} = 200V$	JS-6-T5-2.1
		I_C ($V_{CE} = V_{CEX}$) = 7.5A, V_{CC} = 200V
		R_L = 26.6Ω, L = 1mH*, CR - 1N1204.
		*Miller No. 7871 in weries with Miller No. 7825-3

Item		Test Methods and Test Conditions
3.2.3	continued	V_{BB1} = 12.5V, R_{BB1} = 3Ω, V_{BB2} = 3V, R_{BB2} = 3Ω Duty Cycle = 1%, t_p = 1 ms, R_s = 0.1Ω
3.3.0	Current	
3.3.1	I_C = 7.5A	JS-6-T6 I_B = 1.5A, T_C = 25°C
3.3.2	I_B = 5A	JS-6-T8 T_C = 25°C
3.3.3	I_E = 9.0A	JS-6-T10 I_B = 1.5A, T_C = 25°C
3.4.0	Power	
3.4.1	P_T = 71.4W	JS-6-T12 T_C = 100°C, V_{CB} = 200V, I_C = 0.355A Derating factor = 1.43 W/°C
3.4.2	$P_{TM} = I_C V_{CC}$ = 1125W	JS-6-T13 T_C = 100°C, V_{CC} = 150V, V_{BB} = 3V R_{BB} = 3Ω, I_C = 7.5A, Pulse Width 1ms Duty Cycle = 1%, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$ of Collector Current
3.5.0	Maximum Operating Conditions	
3.5.1	Forward Biased Continuous DC-SOAR	JS-6-T12 (See Figure 1) Test Point: (See 3.4.1)
3.5.2	Pulsed Forward Biased SOAR	JS-6-T14 (See Figure 2) Test Points: T_C = 100°C, V_{BB} = 3V, R_{BB} = 3Ω, Coll. Cu $t_r \leq$ 50us, $t_f \leq 50\mu s$, I_C = 7.5A Duty Cycle $\leq$ 1%, R_S = 0.1Ω

Item		Test Methods and Test Conditions
3.5.2	Continued	1. For t_p = 20ms: V_{CC} = 90V 2. For t_p = 10ms: V_{CC} = 110V 3. For t_p = 5ms: V_{CC} = 125V 4. For t_p = 1ms: V_{CC} = 150V
3.6.0	SOAR Switching between Saturation and Cutoff	
3.6.1	Resistive Load	JS-6-T5.1 with L = 0 and CR disconnected (See Figure 3) Test Points: R_{BB1} = 3Ω, R_{BB2} = 3Ω, V_{BB1} = 12.5V V_{BB2} = 3V, T_C = 100°C, $t_f \leq$ 50us Coll. Current, $t_r \leq$ 50us Coll. Current, R_S = 0.1Ω, I_C = 7.5A, V_{CC} = 200V
3.6.2	Clamped Inductive Load	JS-6-T5.1 (See Figure 4) Test Points: (See 3.2.3)
3.6.3	Unclamped Inductive Load	JS-6-T5-2.1 and CR disconnected (See Figure 5) Test Points: 1. V_{BB_1} = 12.5V, L = 1.4mH* R_{BB_1} = 3Ω, R_L = 3Ω V_{BB_2} = 3V, V_{CC} = 25V R_{BB_2} = 3Ω, f = 60Hz R_S = 0.1Ω, d = 10% 2. V_{BB_1} = 3.0V, L = 10mH** R_{BB_1} = 10Ω, R_L = 7.5Ω V_{BB_2} = 1.5V, V_{CC} = 25.0V R_{BB_2} = 30Ω, f = 60Hz R_S = 0.1Ω, d = 30% *Miller #7871 in series with Miller #7825-3 **Series Stancor C-2688

Item		Test Methods and Test Conditions
3.7.0	Shorted Class B SOAR	(See Figure 6) Test Points: I_C peak = 1.1A, V_{CC} = 200V, R_S = 0.1Ω R_{BB_1} = 5Ω, R_{BB_2} = 10Ω, f = 20Hz, T_C = 100°C
4.0.0	Electrical Characteristics Maximum limits unless otherwise noted Technique: DC - Continuous Operation C.T. - Curve Tracer P - 300μs Pluse, 2% Duty Cycle	T_C = 25°C (unless otherwise noted)
4.1.0	Static	
4.1.1	I_{CEX} = 20mA	V_{CEX} = 200V, V_{BE} = -1.5V, Technique - C.T., T_C = 150°C
	I_{CES} = 100μA	V_{CE} = 240V Technique - C.T.
4.1.2	I_{CEO} = 10mA	V_{CEO} = 200V, Technique - C.T.
4.1.3	I_{EBO} = 20mA	V_{EBO} = 25V, Technique - C.T. T_C = 150°C
4.1.4	V_{CEO} = 200V min	JS-6-T5-2.1 and CR disconnected I_C = 1A, R_{BB_1} = 3Ω, V_{BB_1} = 3V, R_{BB_2} = ∞Ω, d = 50%, f = 60Hz L = 10mH, R_L = 0.1Ω, R_S = 0.1Ω Adjust V_{CC} for specified I_C.

Item		Test Methods and Test Conditions
4.1.5	h_{FE} = 10 min	V_{CE} = 4V, I_C = 5A, Technique - C.T.
	h_{FE} = 7.5 min	V_{CE} = 4V, I_C = 7.5A Technique - C.T.
4.1.6	$V_{CE(sat)}$ = 2.5V	I_C = 5A, I_B = .75A, Technique - C.T.
4.2.0	Dynamic	
4.2.1	f_{hfe} = 10KHz min, 40KHz max	I_C = 1A, V_{CE} = 5V
5.0.0	Thermal Characteristics	
5.1.0	$T_{J\ min}$ = 70ms	I_C = 2A, V_{CE} = 10V, T_C = 25°C MIL-STD-750 Method 3146.1
5.2.0	θ_{JC} = 0.7 °C/W	I_C = 2A, V_{CE} = 10V, T_C = 25°C MIL-STD-750 Method 3136

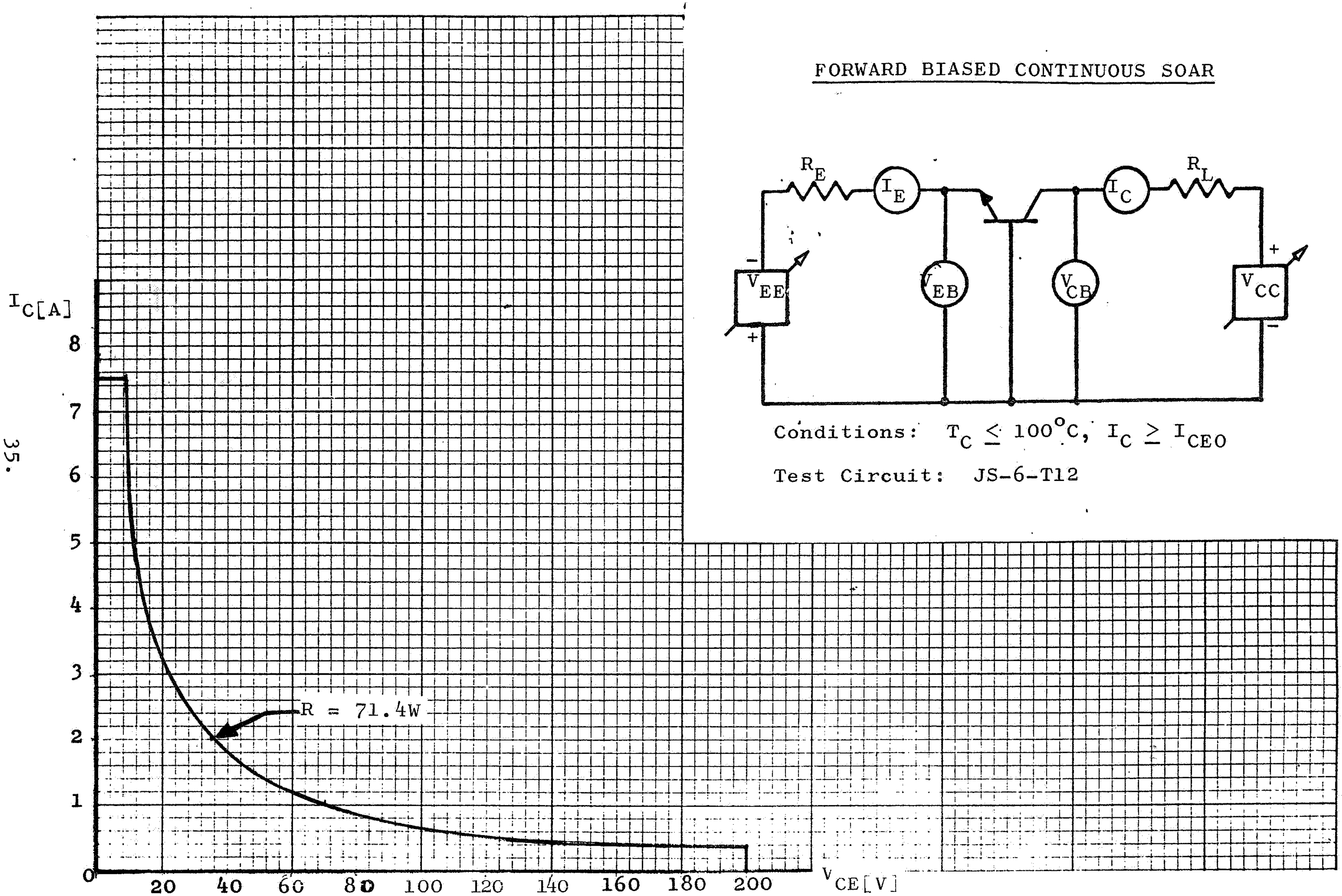
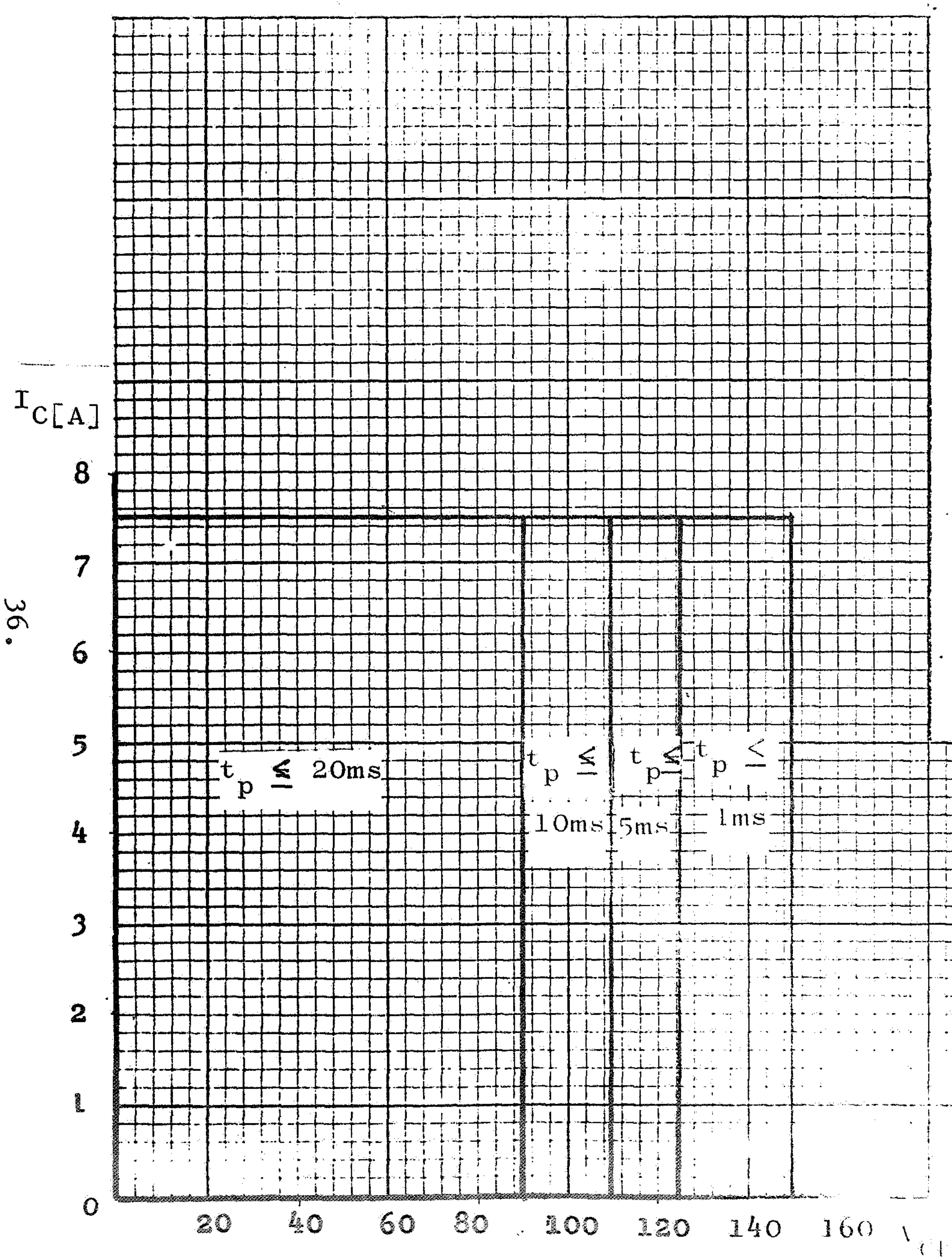
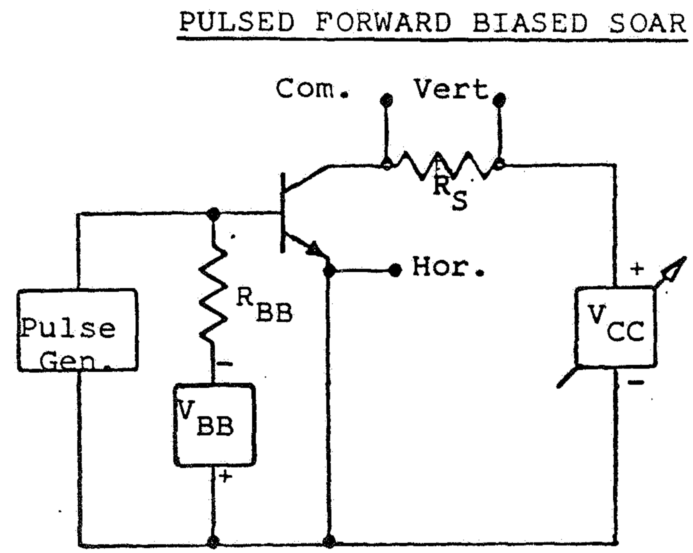

FORWARD BIASED CONTINUOUS SOAR
R_E
I_E
V_{EE}
V_{EB}
V_{CB}
I_C
R_L
V_{CC}
Conditions: $T_C \leq 100^{o}C$, $I_C \geq I_{CEO}$
Test Circuit: JS-6-T12
$I_{C[A]}$
8
7
6
5
4
3
2
1
0
20
40
60
80
100
120
140
160
180
200
$V_{CE[V]}$
R = 71.4W

Figure 1





Test Circuit: JS-6-T14

Figure 2

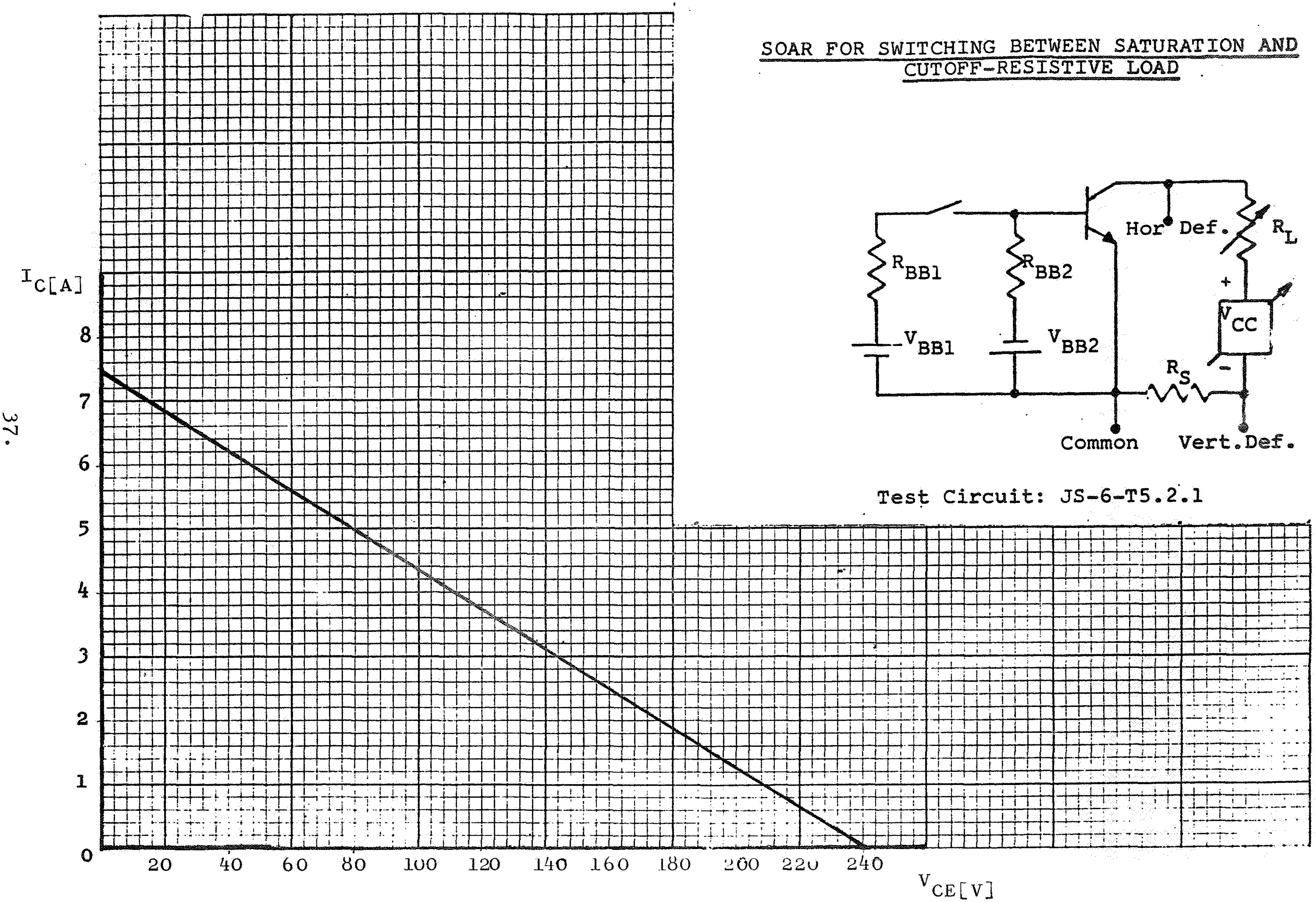

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD
R_{BB1}
V_{BB1}
R_{BB2}
V_{BB2}
Hor. Def.
R_L
+
V_{CC}
−
R_S
Common
Vert.Def.
Test Circuit: JS-6-T5.2.1
I_C[A]
0
1
2
3
4
5
6
7
8
20
40
60
80
100
120
140
160
180
200
220
240
V_{CE}[V]

Figure 3

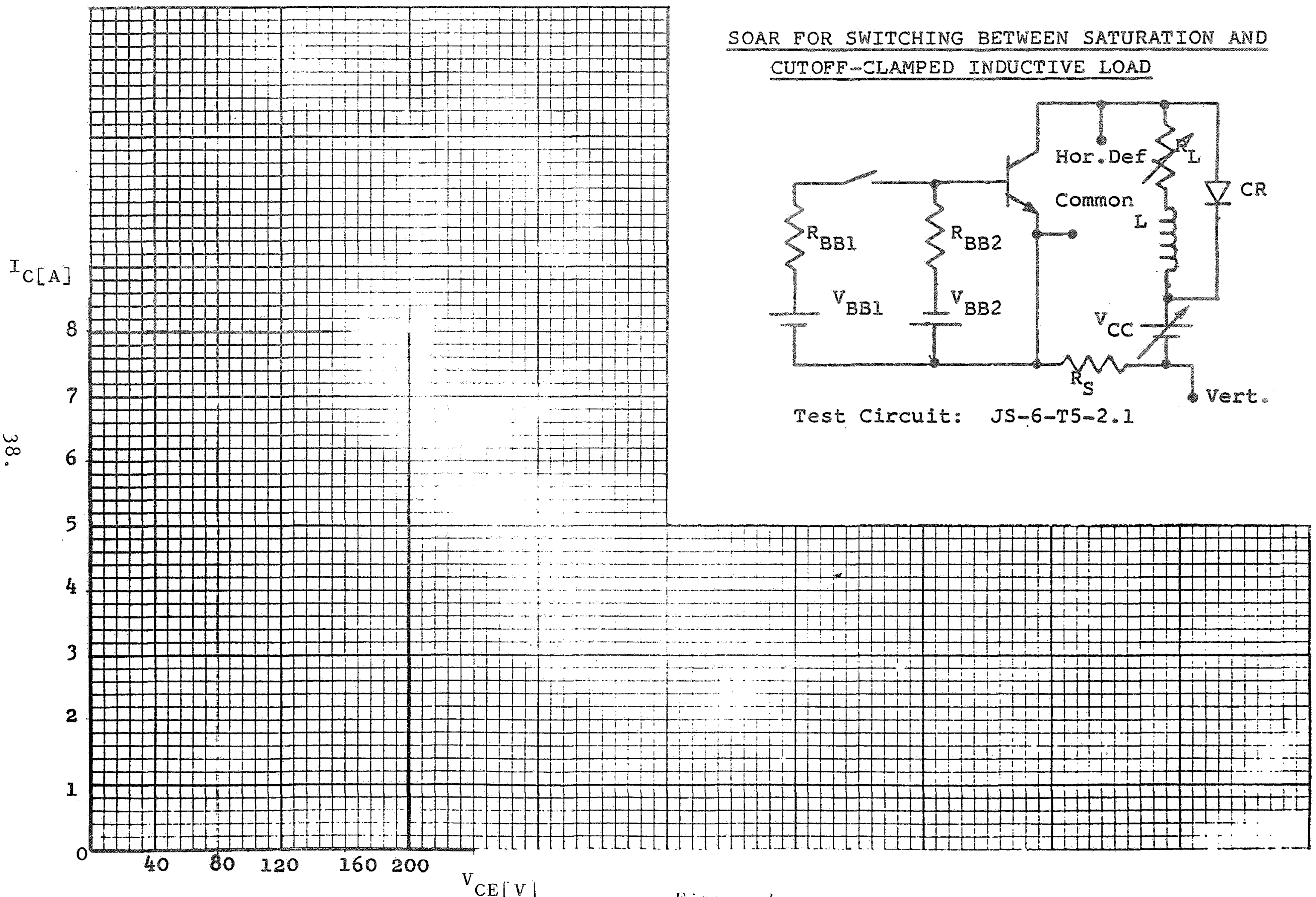

I_C[A]
8
7
6
5
4
3
2
1
0
40
80
120
160
200
V_{CE}[V]
SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-CLAMPED INDUCTIVE LOAD
R_{BB1}
V_{BB1}
R_{BB2}
V_{BB2}
Hor.Def
Common
R_L
L
CR
V_{CC}
R_S
Vert.
Test Circuit: JS-6-T5-2.1

Figure 4

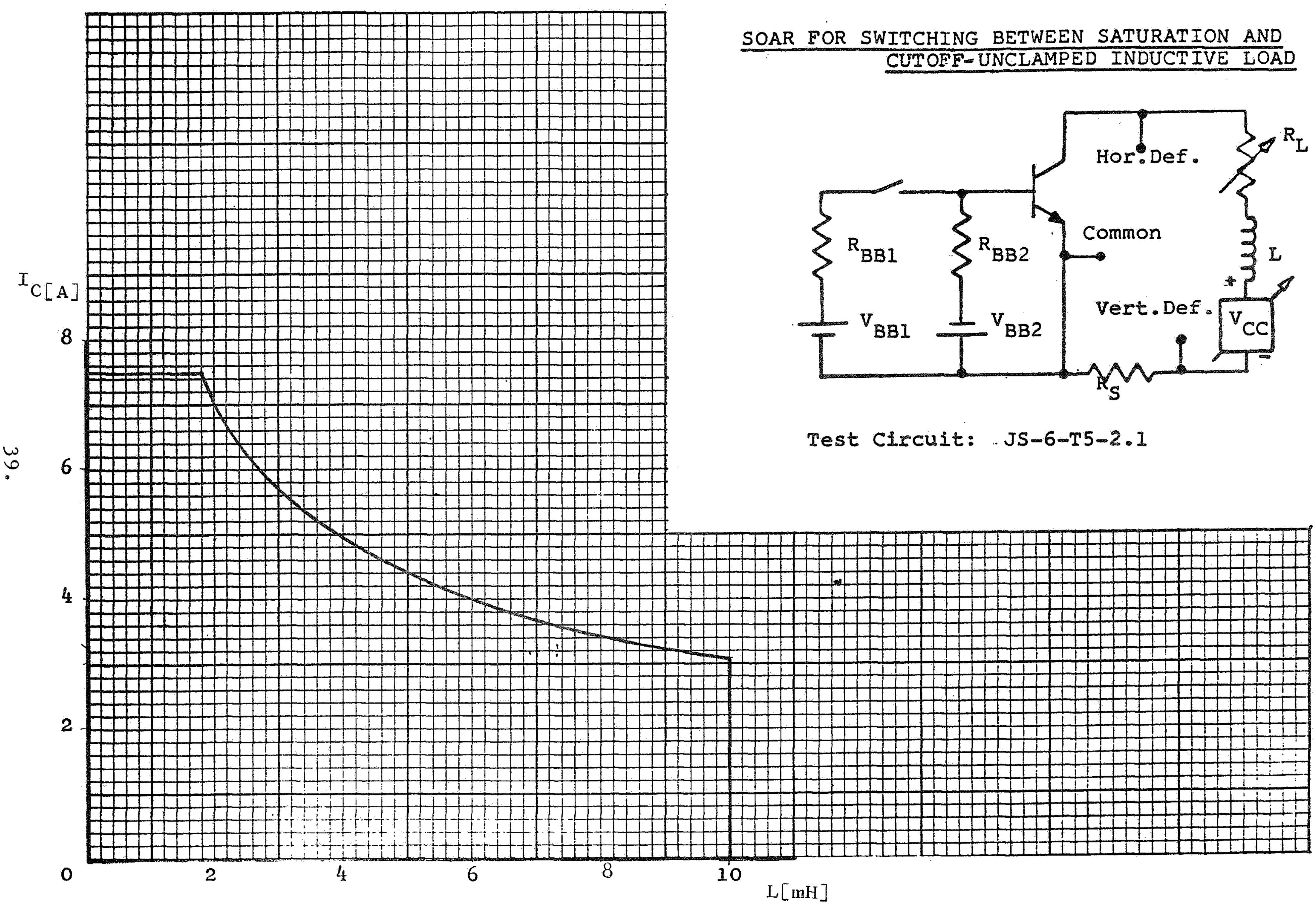

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD
$I_{C}[A]$
8
6
4
2
0
2
4
6
8
10
L[mH]
R_{BB1}
V_{BB1}
R_{BB2}
V_{BB2}
Hor.Def.
Common
Vert.Def.
R_L
L
V_{CC}
R_S
Test Circuit: JS-6-T5-2.1

Figure 5

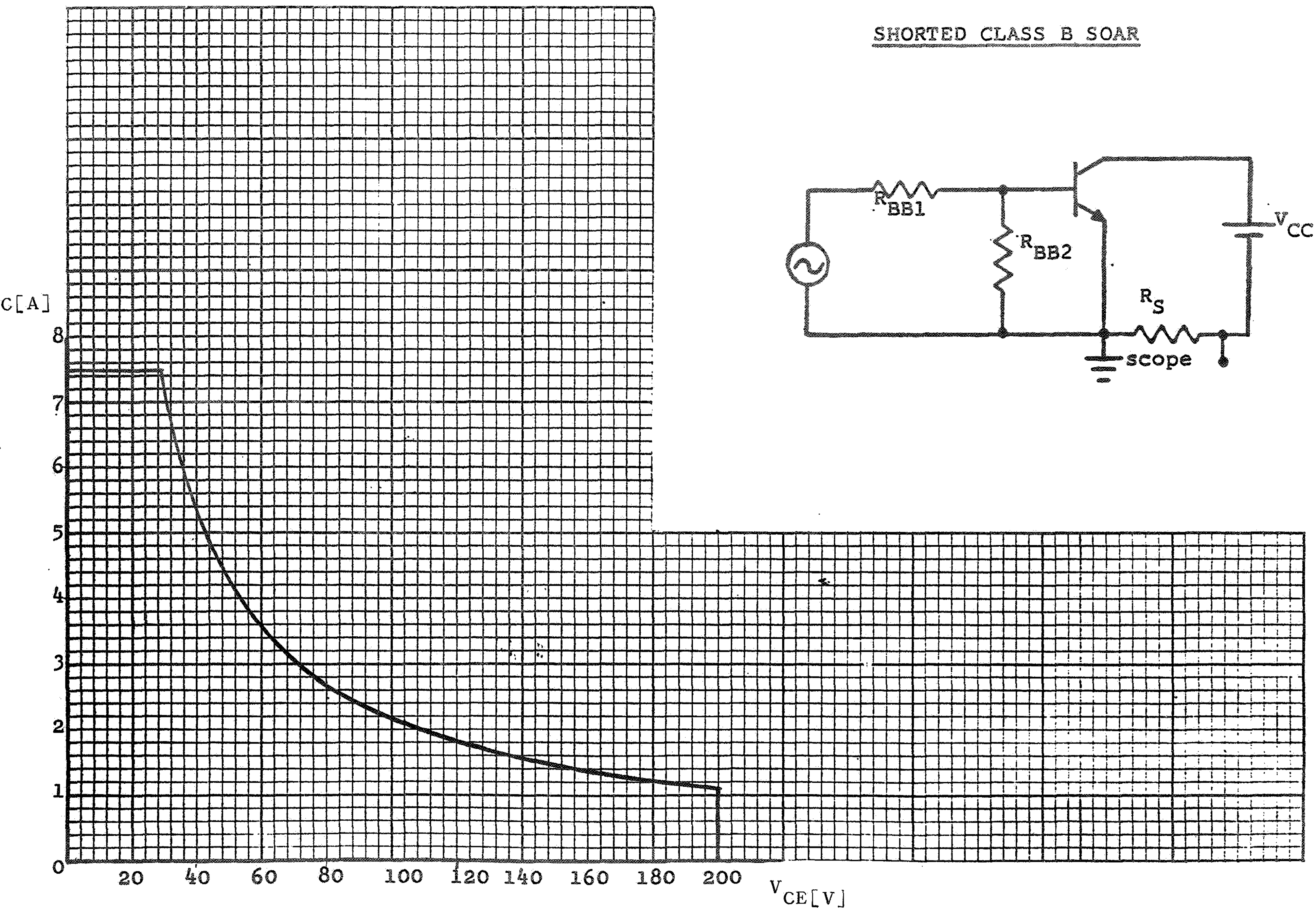

SHORTED CLASS B SOAR
R_{BB1}
R_{BB2}
V_{CC}
R_S
scope
$I_{C}[A]$
8
7
6
5
4
3
2
1
0
20
40
60
80
100
120
140
160
180
200
$V_{CE}[V]$

Figure 6

Silicon Power Transistor

< Type 2N1514 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer H --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract No. NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item		Test Methods and Test Conditions
1.0.0	General Description	
1.1.0	Type NPN	
1.2.0	Material -- Silicon	
2.0.0	Mechanical Data	
2.1.0	Outline -- TO-36	
2.2.0	Terminal Designation	
	1 -- Base	
	2 -- Emitter	
	3 -- Collector	
	case -- Collector	
3.0.0	Maximum Ratings	
3.1.0	Temperature	
3.1.1	$T_{STG(max)} = +200^{o}C$	JS-6-T1.1 (JEDEC suggested Standard: "Test Procedures for Verification of Maximum Ratings.")
	$T_{STG(min)} = -65^{o}C$	JS-6-T1.2
3.1.2	$T_{J(max)} = 200^{o}C$	JS-6-T2 $T_C = 100^{o}C$ $V_{CB} = 10V$, $I_C = 4.3A$
3.1.3	$T(Lead) = 230^{o}C$	Distance from case - 0.25 in Time - 10s
3.2.0	Voltage	$T_C = 25^{o}C$
3.2.1	$V_{CBO} = 100V$	JS-6-T3 or MIL-STD-750A Method 3001.1

Item		Test Methods and Test Conditions
3.2.2	$V_{EBO} = 10V$	JS-6-T4 or MIL-STD-750A Method 3026.1
3.2.3	$V_{CEX} = 70V$	JS-6-T5.1
		I_C $(V_{CE} = V_{CEX}) = 6A$
		$V_{CC} = 100V$, $R_L = 16.0\Omega$
		$L = 1mH^*$, CR - 1N1204
		$V_{BB1} = 7.5V$, $R_{BB1} = 1\Omega$
		V_{BB2} 8V, $R_{BB2} = 5\Omega$
		$R_S = 0.1\Omega$
		t_p = 1ms, Duty Cycle $\leq$ 1%
		*Miller No. 7871 in series with Miller No. 7825-3
3.3.0	Current	
3.3.1	$I_C = 6A$	JS-6-T6
		$I_B = 2A$, $T_C = 25^\circ C$
3.3.2	$I_B = 3A$	JS-6-T8
		$T_C = 25^\circ C$
3.3.3	$I_E = 8A$	JS-6-T10
		$I_B = 2A$, $T_C = 25^\circ C$
3.4.0	Power	
3.4.1	$P_T = 43W$	JS-6-T12
		$T_C = 100^\circ C$
		$V_{CB} = 10V$, $I_C = 4.3A$
		Derating factor - $0.43W/^\circ C$

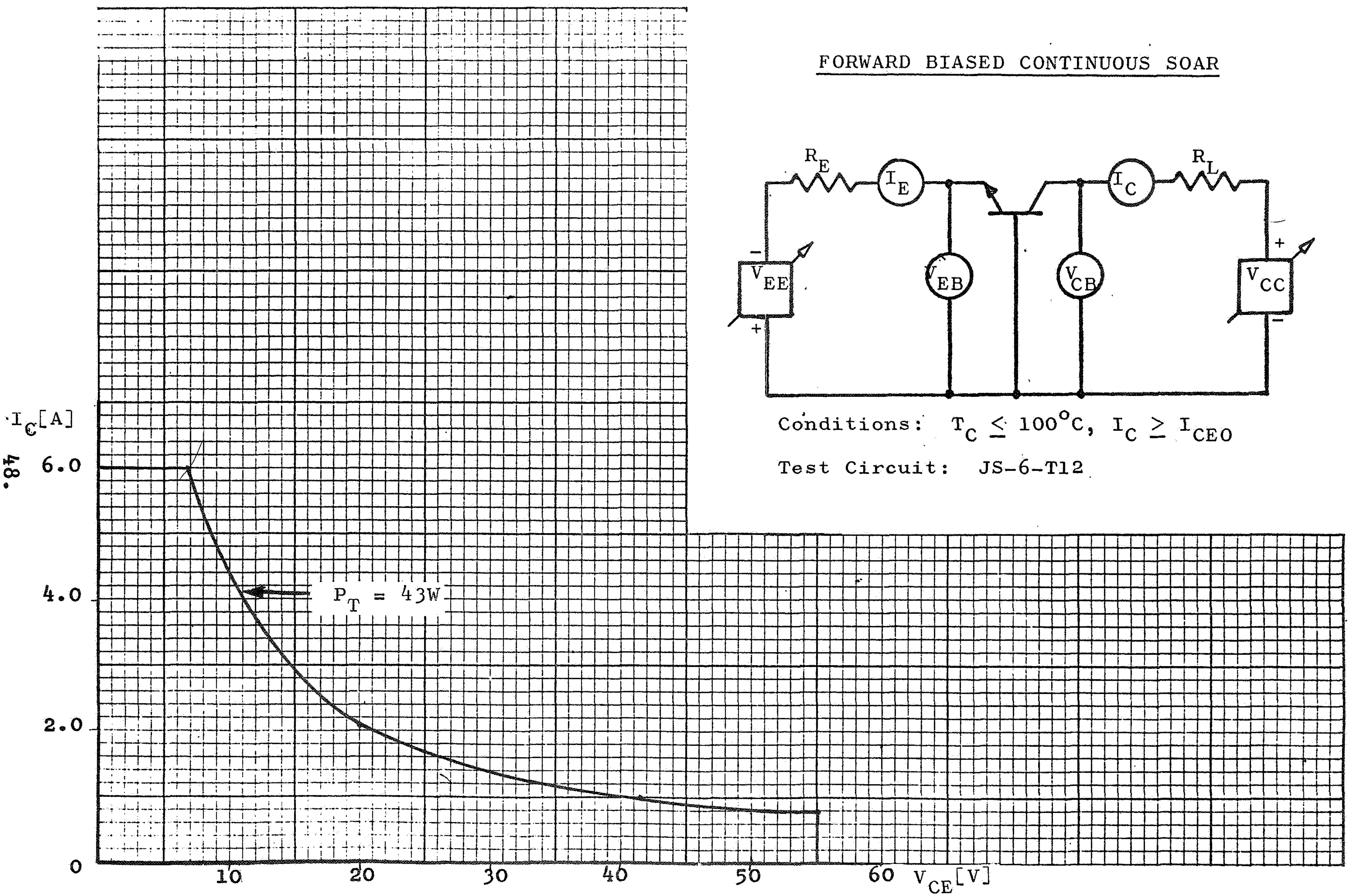
Item		Test Methods and Test Conditions
3.4.2	$P_{TM} = I_C V_{CC} = 330W$	JS-6-T13
		$T_C = 100^oC$
		$V_{CC} = 55V$, $I_C = 6A$
		$V_{BB} = 8V$, $R_{BB} = 5\Omega$
		Input Pulse Characterisitcs
		Pulse Width = 10 ms
		Duty Cycle $\leq$ 1%
		$t_r \leq 50\mu s$, $t_f \leq 50\mu s$ Coll. Current
3.5.0	Maximum Operating Conditions	
3.5.1	Forward Biased Continuous DC-SOAR	JS-6-T12 (See Figure 1)
		Test Point: (See 3.4.1)
3.5.2	Pulsed Forward Biased SOAR	JS-6-T14 (See Figure 2)
		Test Points:
		$T_C = 100^oC$, $V_{BB} = 8V$; $R_{BB} = 5\Omega$
		$t_r \leq 50\mu s$, $t_f \leq 50\mu s$, $I_C = 6A$
		Duty Cycle $\leq$ 1%, $R_S = 0.1\Omega$
		1. For $t_p = 20ms$; $V_{CC} = 30V$
		2. For $t_p = 10ms$; $V_{CC} = 55V$
3.6.0	SOAR	
	Switching between Saturation and Cutoff	
3.6.1	Resistive Load	JS-6-T5-2.1 with L = 0 and CR disconnected (See Figure 3)

Item		Test Methods and Test Conditions
3.6.1	Resistive Load (Cont'd)	
		Test Point:
		$I_C = 6A$, $V_{CC} = 100V$, $R_{BB1} = 1\Omega$,
		$R_{BB2} = 5\Omega$, $R_S = 0.1\Omega$, $V_{BB1} = 7.5V$,
		$V_{BB2} = 8V$, $T_C = 100^\circ C$, (Coll. Current)
		$t_r \leq 50\mu s$, $t_f \leq 50\mu s$
3.6.2	Clamped Inductive Load	JS-6-T5-2.1 (See Figure 4)
		Test Point: (See 3.2.3)
3.6.3	Uclamped Inductive Load	JS-6-T5-2.1 and CR disconnected (See Figure 5)
		Test Points:
		$R_{BB1} = 1\Omega$, $R_{BB2} = 5\Omega$, $R_S = 0.1\Omega$,
		$V_{BB1} = 7.5V$, $V_{BB2} = 8V$, $T_C = 25^\circ C$,
		$f = 60Hz$, $d = 10\%$
		1. $I_C = 6A$, $V_{CC} = 18V$, $R_L = 2\Omega$, $L=10mH$*
		2. $I_C = 2.5A$, $V_{CC} = 28V$, $R_L = 10\Omega$, $L=40mH$
		*Stancor - C-2688 **Series Stancor-C-2688
3.7.0	Shorted Class B SOAR	(See Figure 6)
		Test Point:
		I_C peak $= 2.6A$, $V_{CC} = 55V$, $R_S = 0.1\Omega$,
		$R_{BB1} = 1\Omega$, $R_{BB2} = 3\Omega$, $f = 20Hz$,
		$T_C = 100^\circ C$

Item		Test Methods and Test Conditions
4.0.0	Electrical Characteristics	$T_C = 25^{o}C$ [unless otherwise noted]
	Maximum limits unless otherwise noted	
	Technique:	
	DC - Continuous Operation	
	C.T. - Curve Tracer	
	P - 300µs Pulse, 2% Duty Cycle	
4.1.0	Static	
4.1.1	$I_{CEO} = 100mA$	$V_{CE} = 55V$ Technique - C.T.
4.1.2	$I_{CBO} = 2mA$	$V_{CB} = 30V$, $T_C = 200^{o}C$ Technique - C.T.
4.1.3	$V_{EBF} = 1.5V$	$V_{CB} = 30V$, $T_C = 200^{o}C$ Technique - C.T.
4.1.4	$I_{EBO} = 25\mu A$	$V_{EB} = 10V$, Technique - C.T.
4.1.5	$V_{(BR)CEO} = 55$ minV	$I_C = 100mA$ Technique - C.T.
4.1.6	$h_{FE} = 25$ min " $= 75$ max	$V_{CE} = 4V$, $I_C = 1.5A$ Technique - C.T.
4.1.7	$h_{FE} = 7$ min	$V_{CE} = 8V$, $I_C = 6A$ Technique - P
4.1.8	$V_{CE(sat)} = 6$ max V	$I_C = 6A$, $I_B = 2A$ Technique - C.T.
4.1.9	$V_{BE} = 7.8$ max V	$I_C = 6A$, $V_{CE} = 8V$ Technique - P

Item		Test Methods and Test Conditions
5.0.0	Thermal Characteristics	
5.1.0	$T_{J\ min} = 5ms$	$I_C = 2A$, $V_{CE} = 10V$, $T_C = 25^oC$ MIL-STD-750 Method 3146.1
5.2.0	$\Theta_{JC\ max} = 2.33^oC/W$	$I_C = 2A$, $V_{CE} = 10V$, $T_C = 25^oC$ MIL-STD-750 Method 3136
6.0.0	f_{hfe} = 10KHz(min) 40KHz(max)	$I_C = 100mA$, $V_{CE} = 6C$ MIL-STD-750 Method

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^\circ C$, $I_C \geq I_{CEO}$

Test Circuit: JS-6-T12

Figure 1

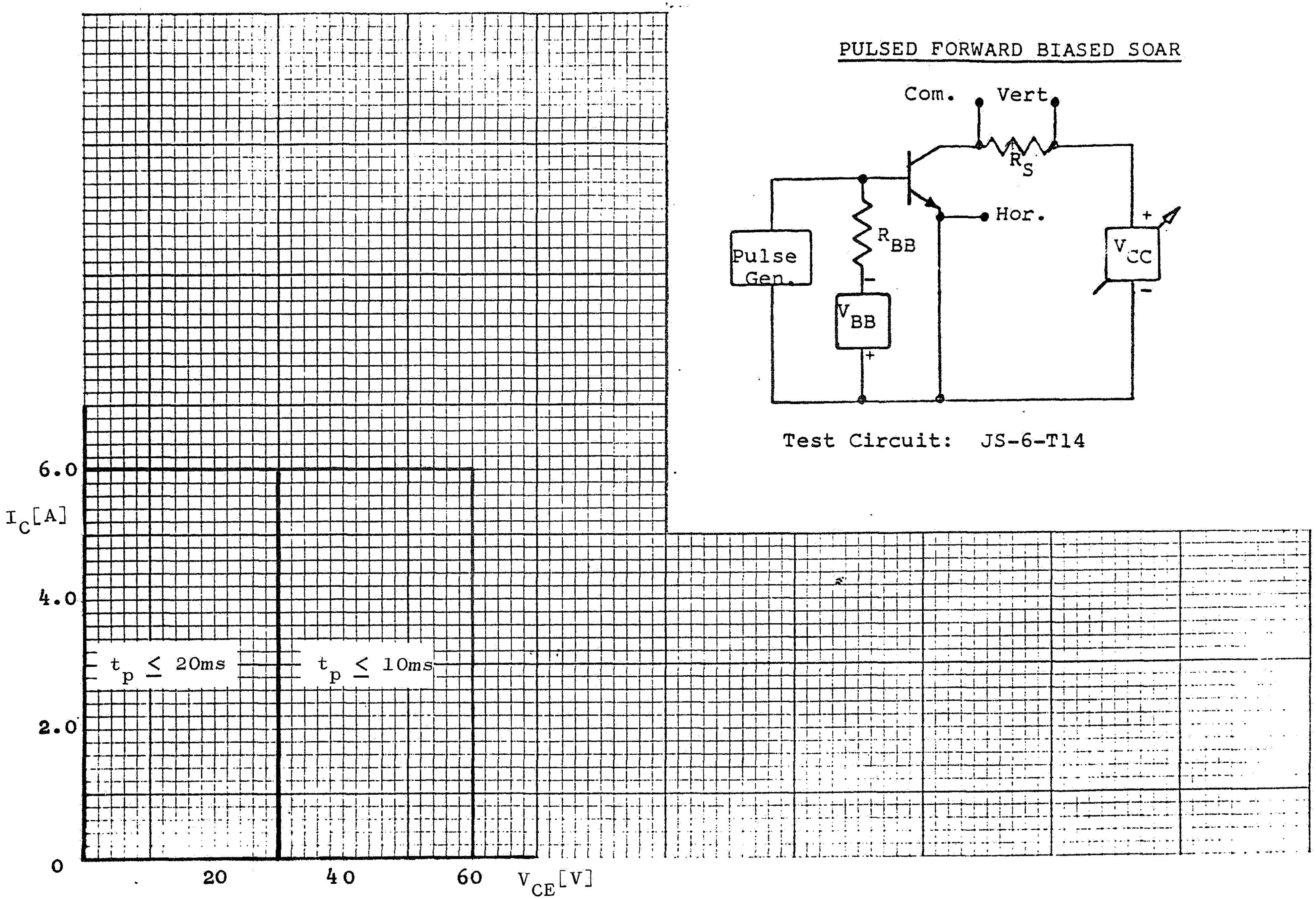

PULSED FORWARD BIASED SOAR
Com.
Vert
R_S
Hor.
R_{BB}
Pulse Gen.
V_{BB}
V_{CC}
Test Circuit: JS-6-T14
6.0
I_C[A]
4.0
2.0
0
20
40
60
V_{CE}[V]
$t_p \leq$ 20ms
$t_p \leq$ 10ms

Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

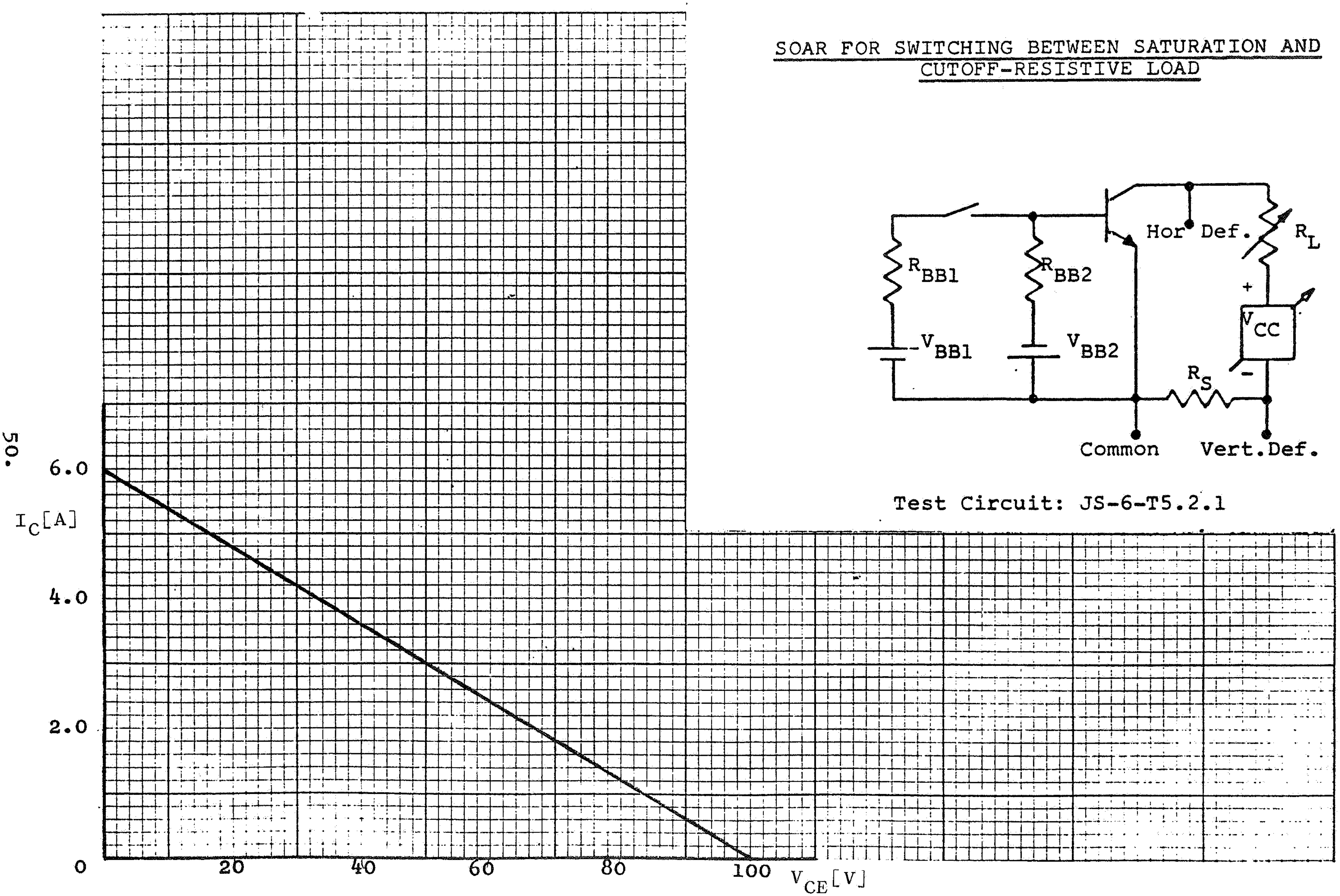
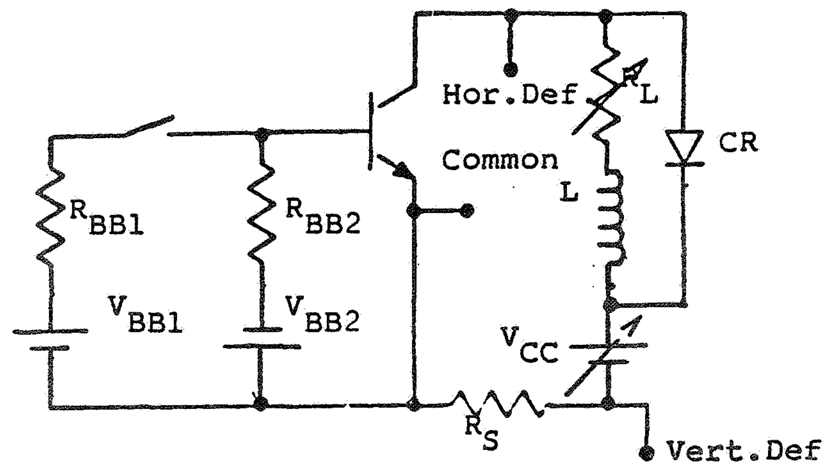


Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

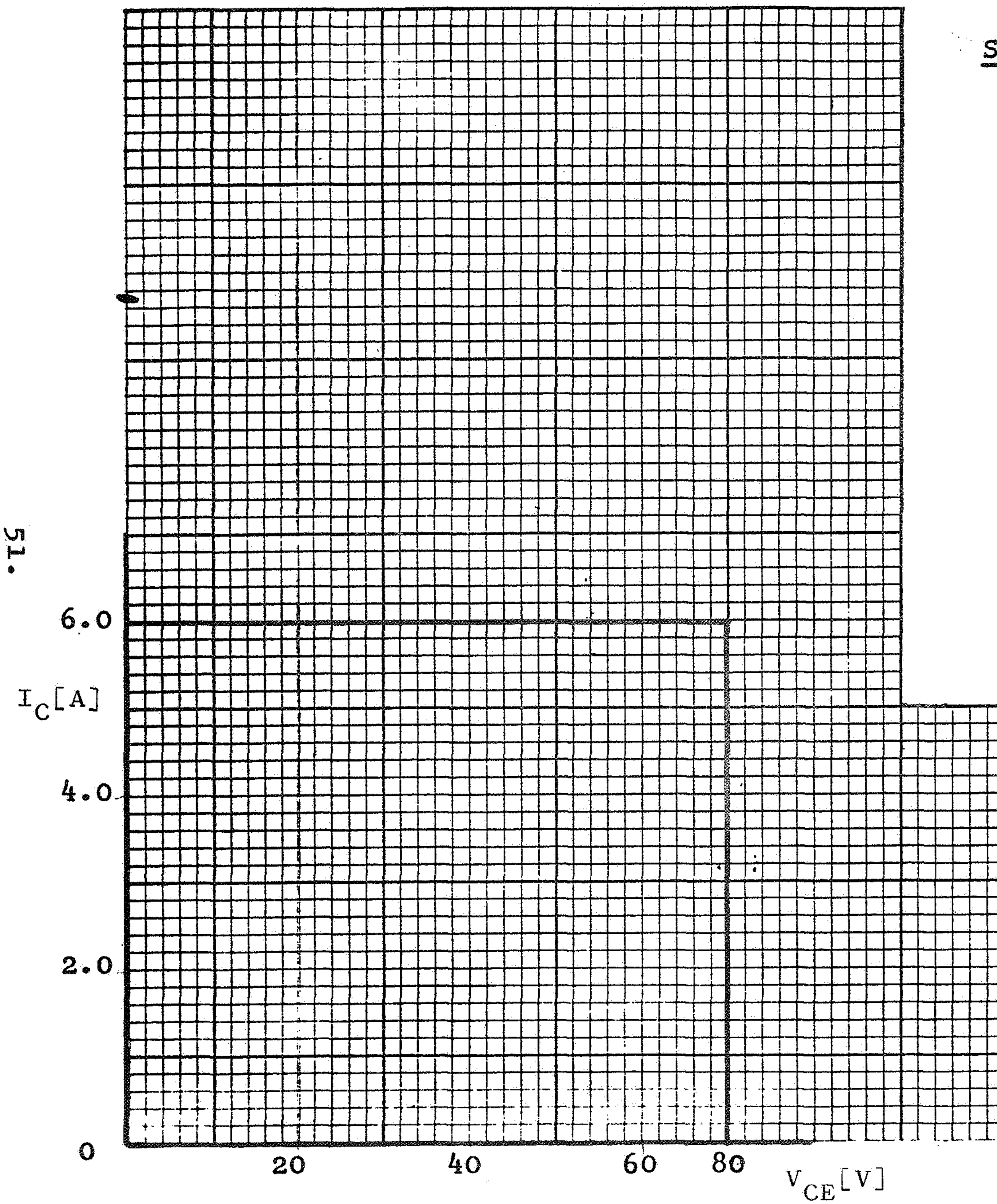


Figure 4

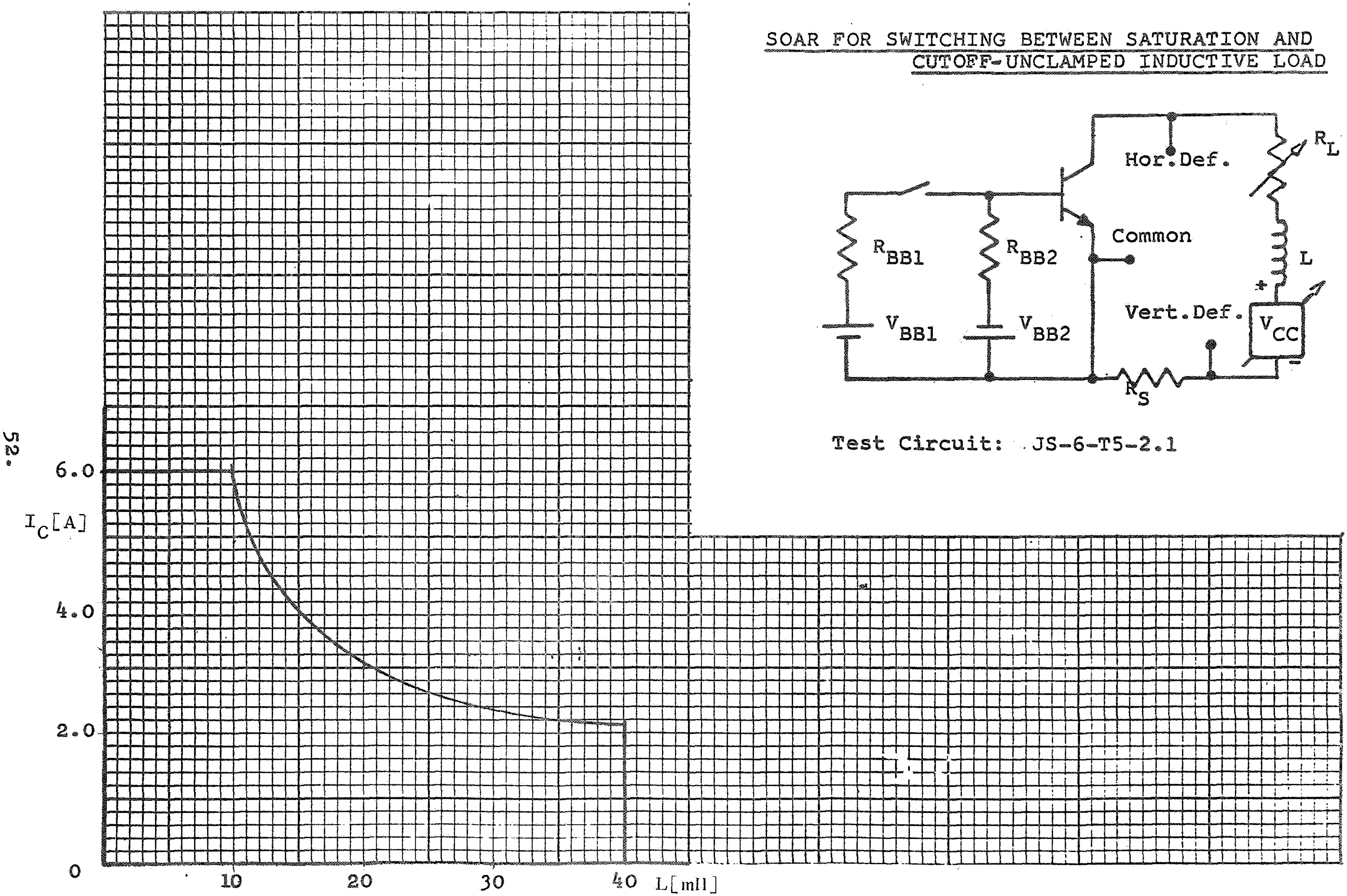

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD
Hor. Def.
Common
Vert. Def.
R_L
L
V_{CC}
R_{BB1}
R_{BB2}
V_{BB1}
V_{BB2}
R_S
Test Circuit: JS-6-T5-2.1
6.0
I_C[A]
4.0
2.0
0
10
20
30
40
L[mH]

Figure 5

SHORTED CLASS B SOAR

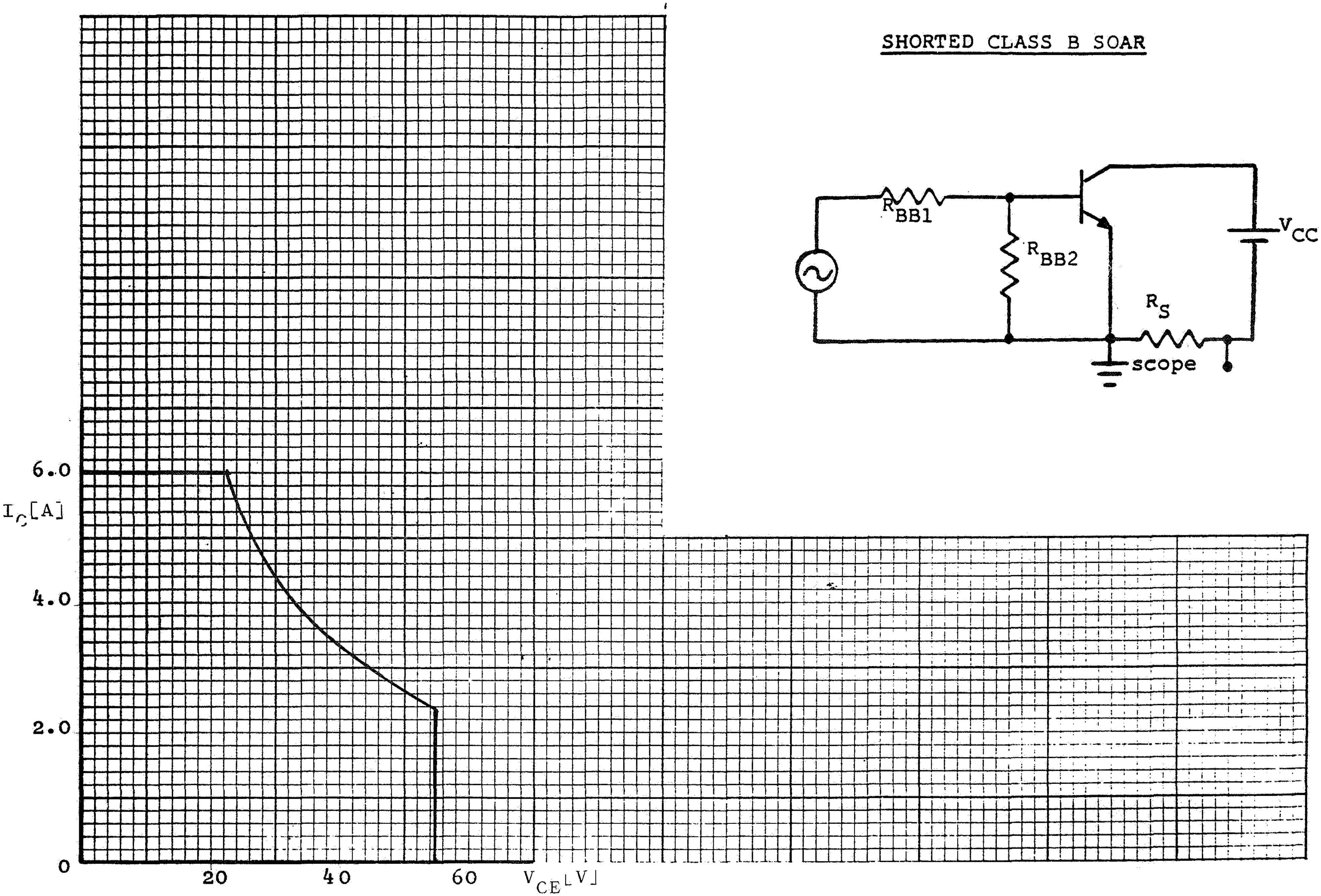


Figure 6

SILICON POWER TRANSISTOR

< Type 2N2102 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturers D & J --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item		Test Methods and Test Conditions
1.0.0	General Description	
1.1.0	Type - NPN	
1.2.0	Material - Silicon	
2.0.0	Mechanical Data	
2.1.0	Outline - TO-5	
2.2.0	Terminal Designation	
	1 - Base	
	2 - Emitter	
	3 - Collector	
	Case - Collector	
3.0.0	Maximum Ratings	
3.1.0	Temperature	
3.1.1	$T_{STG(min)} = -65^{\circ}C$ $T_{STG(max)} = +200^{\circ}C$	JS-6-T1.1 [JEDEC Suggested Standard: "Test Procedure for Verification of Maximum Ratings" JEDEC Publication No. 65]
3.1.2	$T_{J(max)} = 200^{\circ}C$	JS-6-T2 $T_C = 100^{\circ}C$, $P_T = 2.86W$, $I_C = 55mA$
3.1.3	T(Lead) = $300^{\circ}C$	Distance from case 1/16" $\pm$ 1/32" Time = 10 sec (max)
3.2.0	Voltage	
3.2.1	$V_{(BR)CBO} = 120V$	JS-6-T3
3.2.2	$V_{(BR)EBO} = 7V$	JS-6-T4

Item		Test Methods and Test Conditions
3.2.3	$V_{(BR)CEO} = 65V$	JS-6-T5.1 CR Disconnected $I_C = 0.1A$, $R_{BB1} = 25\Omega$, $V_{BB1} = 5V$, $R_{BB2} = \infty\Omega$, $d = 50\%$, $f = 60Hz$, $L^* = 5.0mH$, $R_L = 0$, $R_S = 1.0\Omega$ Adjust V_{CC} for specified I_C *Chicago Standard Transformer Corp. C-2689
3.3.0	Current	
3.3.1	$I_C = 1.0A$	JS-6-T6 $I_B = 0.3A$, $T_C = 25^oC$
3.3.2	$I_B = 0.3A$	JS-6-T8 $T_C = 25^oC$
3.3.3	$I_E = 1.3A$	JS-6-T10 $I_B = 0.3A$, $T_C = 25^oC$
3.4.0	Power	
3.4.1	$P_T = 2.86W$	JS-6-T12 Test Point: See 3.1.2
3.4.2	$P_{TM} = I_C V_{CC} = 80W$	JS-6-T13 $T_C = 25^oC$, $V_{CC} = 80$, $V_{BB} = 5V$, $R_{BB} = 25$, $I_C = 1.0A$, Pulse Width=$100\mu s$ Duty Cycle $\leq 2\%$, $t_r \leq 5\mu s$ $t_f \leq 5\mu s$
3.5.0	Maximum Operating Conditions	

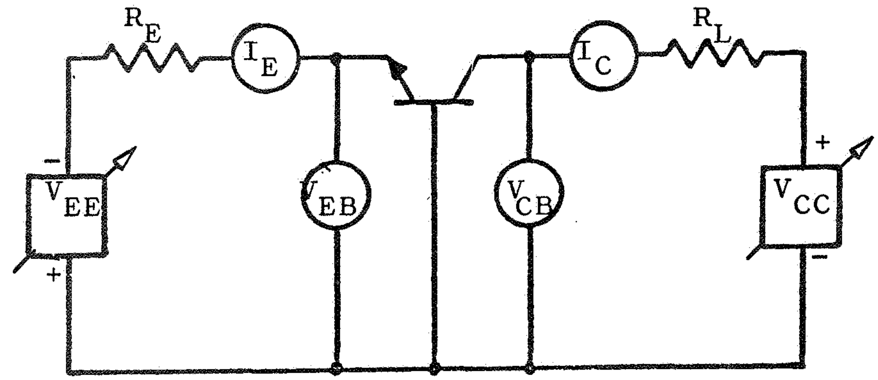
Item		Test Methods and Test Conditions
3.5.1	Forward Biased Continuous DC-SOAR	JS-6-T12 Test Points: See 3.1.2
3.5.2	Pulsed Forward Biased SOAR	JS-6-T14 Test Points: $T_C = 100^oC$, $V_{BB} = 5V$, $R_{BB} = 20\Omega$, $t_r \leq 5\mu s$, $t_p \leq 5\mu s$, $I_C = 1.0A$, Duty Cycle $\leq 2\%$, $R_S = 1.0\Omega$ 1. t_p = 1ms: $V_{CC} = 35V$ 2. $t_p = 500\mu s$: $V_{CC} = 45V$ 3. $t_p = 100\mu s$: $V_{CC} = 80V$
3.6.0	SOAR Switching between Saturation and cutoff	
3.6.1	Resistive Load	JS-6-T5.1 with L = 0 and CR disconnected Test Points: $R_{BB1} = 20\Omega$, $R_{BB2} = 100\Omega$, $V_{BB1} = 8.0V$, $V_{BB2} = 5V$, $T_C = 100^oC$, $t_f \leq 5\mu s$, $t_r \leq 5\mu s$, $R_S = 1.0\Omega$, $R_L = 78\Omega$, $V_{CC} = 80V$, d = 10%
3.6.2	Clamped Inductive Load	JS-6-T5.1 Test Point: $I_C \leq 1.0A$, $V_{CE} = 80V$, $R_{BB1} = 20\Omega$, $R_{BB2} = 100\Omega$, $V_{BB1} = 8V$, $V_{BB2} = 5V$, $R_L = 8\Omega$, L* = 1.0mH, *J.W.Miller: 7871 in weries with 7825-3

Item		Test Methods and Test Conditions
3.6.3	Unclamped Inductive Load	JS-6-T5.1 and CR disconnected Test Points: 1. $V_{BB1} = 8.0V$ $L^* = 1.0mH$ $R_{BB1} = 20\Omega$ $R_L = 66.66\Omega$ $V_{BB2} = 5.0V$ $V_{CC} = 10V$ $R_{BB2} = 100\Omega$ $f = 60Hz$ $R_S = 1.0\Omega$ $d = 10\%$ *J.W. Miller: 7871 in series with 7825-3 2. $V_{BB1} = 8.0V$ $L^* = 50\mu H$ $R_{BB1} = 20\Omega$ $R_L = 7\Omega$ $V_{BB2} = 5V$ $V_{CC} = 10V$ $R_{BB2} = 100\Omega$ $f = 60Hz$ $R_S = 1.0\Omega$ $d = 10\%$ *J.W. Miller: 7825-8
3.7.0	Shorted Class B SOAR	(See Figure 6) Test Points: I_C peak = 0.22A, $V_{CC} = 32.5V$, $R_S = 1.0\Omega$, $R_{BB1} = 20\Omega$, $R_{BB2} = 100\Omega$ $f = 20Hz$, $T_C = 100^oC$
4.0.0	Electrical Characteristics Maximum limits unless otherwise noted Technique: DC - Continuous Operation C.T. - Curve Tracer P - 300μs Pulse, 2% Duty Cycle	$T_C = 25^oC$ (unless otherwise noted)

Item		Test Methods and Test Conditions
4.1.0	Static	
4.1.1	I_{CBO} = 2.0nA	V_{CB} = 60V, Technique MIL-STD-3036-10
4.1.2	I_{CBO} = 2.0μA	V_{CB} = 60V, T_C = 150°C, Technique MIL-STD-3036-D
4.1.3	I_{EBO} = 2.0nA	V_{BE} = -5V, Technique MIL-STD-3061-D
4.1.4	$V_{(BR)CEO}$ = 65V min	JS-6-T5.1 (See 3.2.3)
4.1.5	$V_{(BR)CER}$ = 80V min	JS-6-T5.1 (See 3.2.3 except R_{BB2} = 10Ω, V_{BB2} = 0)
4.1.6	$V_{(BR)CBO}$ = 120V min	I_C = 1mA Technique C.T.
4.1.7	$V_{(BR)EBO}$ = 7V min	I_E = 1mA Technique C.T.
4.1.8	h_{FE} = 10 min	I_C = 1A, V_{CE} = 10V, Technique - P
4.1.9	h_{FE} = 25 min	I_C = 0.5A, V_{CE} = 10V Technique P
4.1.10	h_{FE} = 40 min 120 max	I_C = 150mA, V_{CE} = 10V Technique P
4.1.11	h_{FE} = 10 min	I_C = 10mA, V_{CE} = 10V Technique C.T.
4.1.12	h_{FE} = 20 min	I_C = 0.1mA, V_{CE} = 10V Technique C.T.
4.1.13	h_{FE} = 35 max	I_C = 10mA, V_{CE} = 10V, T_C = 55°C Technique C.T.
4.1.14	$V_{CE(S)}$ = 2.0V max	I_C = 1.0A, I_B = 0.2A Technique C.T.
4.1.15	$V_{CE(S)}$ = 0.5V max	I_C = 150mA, I_B = 15mA Technique C.T.
4.1.16	$V_{BE(S)}$ = 2.5V max	I_C = 1.0A, I_B = 0.2A Technique C.T.
4.1.17	$V_{BE(S)}$ = 1.1V max	I_C = 150mA, I_B = 15mA Technique C.T.
4.1.18	I_{CEO} = 1.0μA max	V_{CEO} = 55V Technique D.C.
4.1.19	V_{BEF} = 1.5V max	V_{CB} = 120V Technique C.T.
4.2.0	Dynamic	
4.2.1	$t_d + t_r + t_f$ = 30ns	Circuit specified with registered spec.

Item		Test Methods and Test Conditions
4.2.2	h_{fe} = 30 min, 100 max	I_C = 1.0mA, V_{CE} = 5V, f = 1.0KHz
4.2.3	h_{fe} = 35 min, 150 max	I_C = 5.0mA, V_{CE} = 10V, f = 1.0KHz
4.2.4	h_{fe} = 3 min, 10 max	I_C = 50mA, V_{CE} = 10V, f = 20MHz
4.2.5	NF = 6db	I_C = 0.3mA, V_{CE} = 10V, f = 1KHz R = 1KΩ circuit bandwidth 1Hz
4.2.6	C_{obo} = 15pf	V_{CB} = 10V
4.2.7	C_{ibo} = 80pF	V_{BE} = 0.5V
4.2.8	h_{ob} = 0.1 μmhos min	I_C = 1.0mA, V_{CE} = 5V, f = 1KHz
4.2.9	h_{ob} = 0.1 μmhos min 1.0 μmhos max	I_C = 5.0mA, V_{CE} = 10V, f = 1KHz
4.2.10	h_{ib} = 24Ω min, 34Ω max	I_C = 1.0mA, V_{CE} = 5V, f = 1KHz
4.2.11	h_{ib} = 4Ω min, 8Ω max	I_C = 5.0mA, V_{CE} = 10V, f = 1KHz
4.2.12	h_{rb} = 3×10^{-4}	I_C = 1.0mA, V_{CE} = 5.0V, f = 1KHz
4.2.13	h_{rb} = 3×10^{-4}	I_C = 5.0mA, V_{CE} = 10V, f = 1KHz
5.0.0	Thermal Characteristics	
5.1.0	τ_J = 75ms min	
5.2.0	θ_{JC} = 35°C/W max	
5.2.1	θ_{JA} = 175°C/W max	

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^oC$, $I_C \geq I_{CEO}$

Test Circuit: JS-6-T12

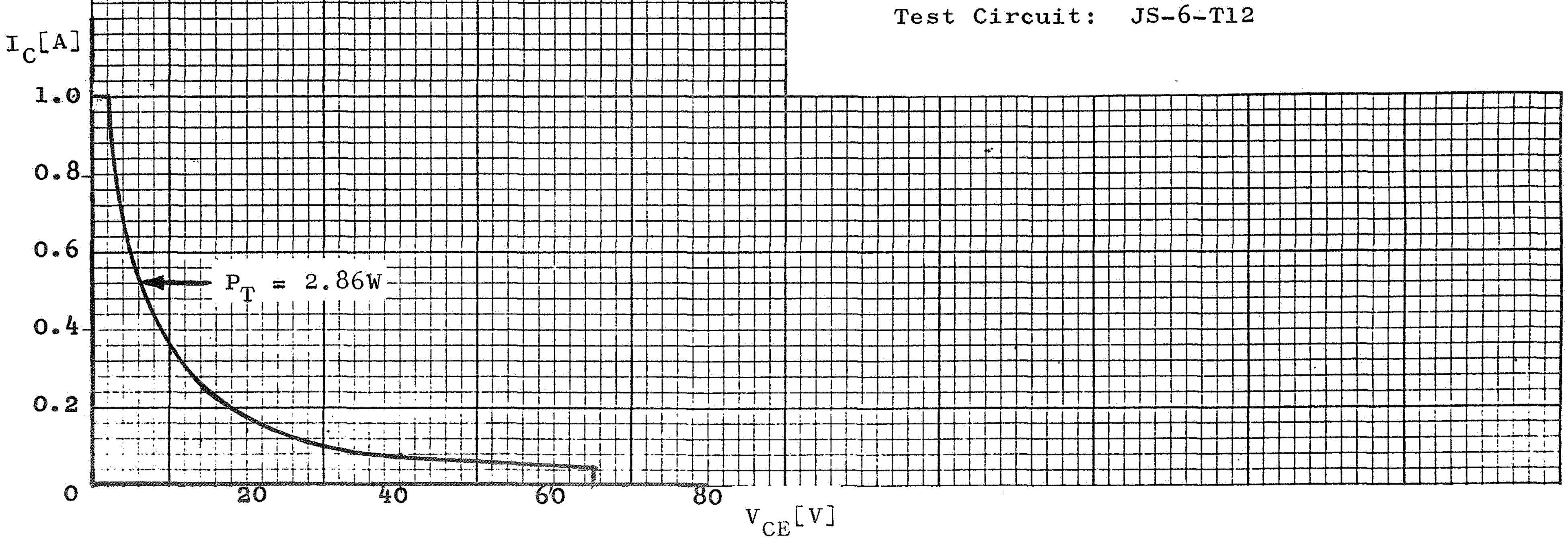


Figure 1

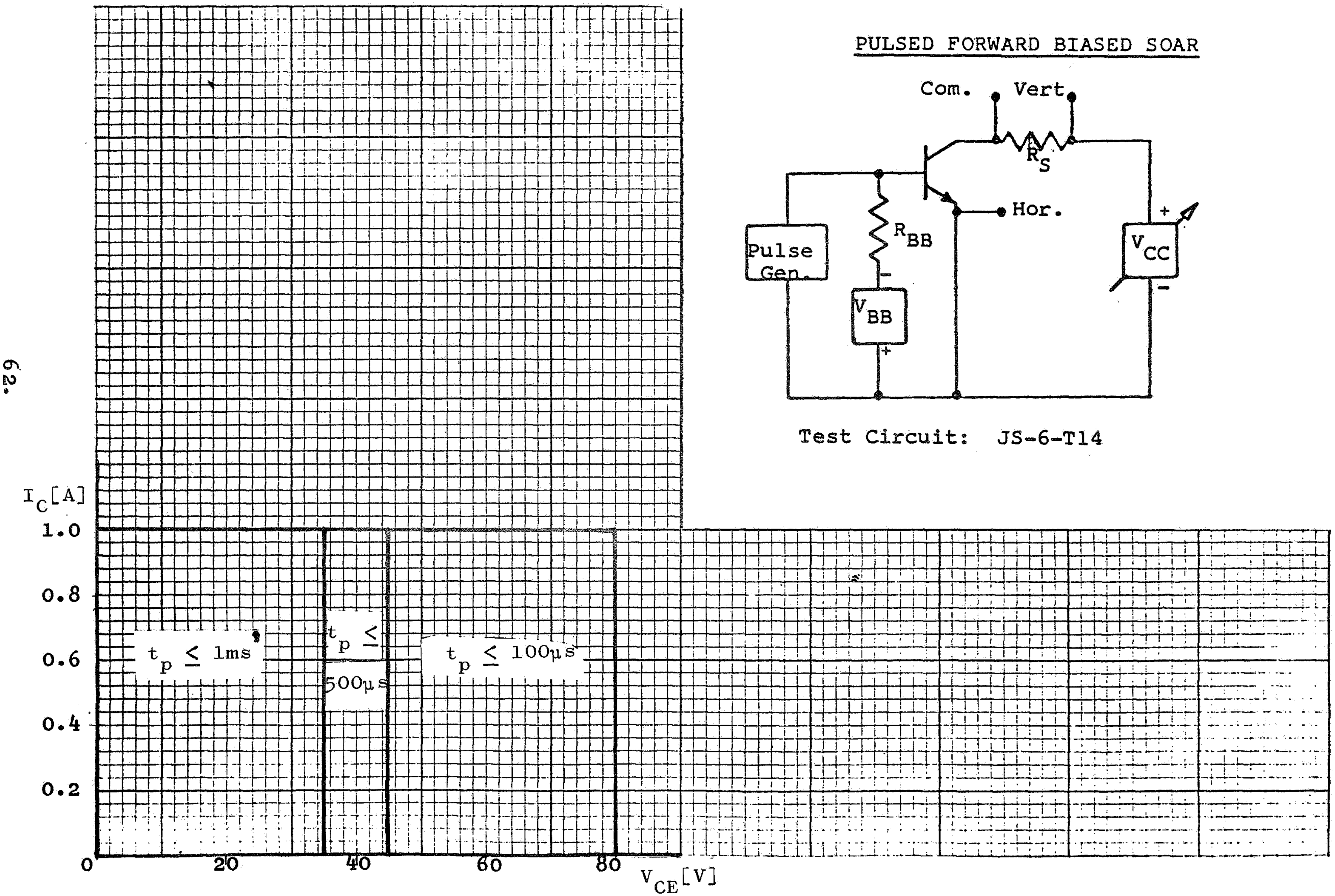

PULSED FORWARD BIASED SOAR
Com.
Vert.
R_S
Hor.
R_{BB}
Pulse Gen.
V_{BB}
V_{CC}
Test Circuit: JS-6-T14
I_C[A]
1.0
0.8
0.6
0.4
0.2
0
20
40
60
80
V_{CE}[V]
$t_p \leq$ 1ms
$t_p \leq$ 500μs
$t_p \leq$ 100μs

Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

Test Circuit: JS-6-T5.2.1

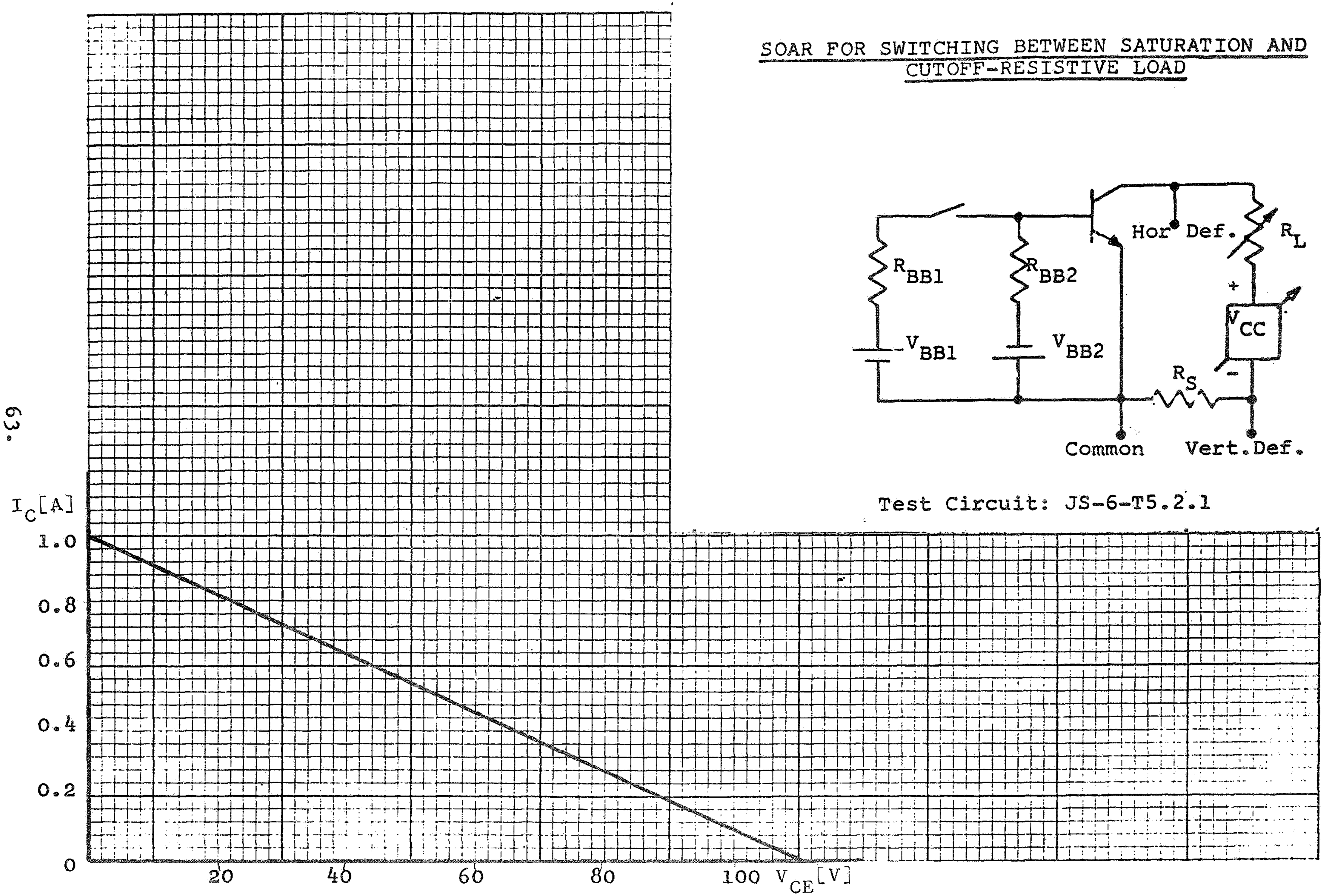
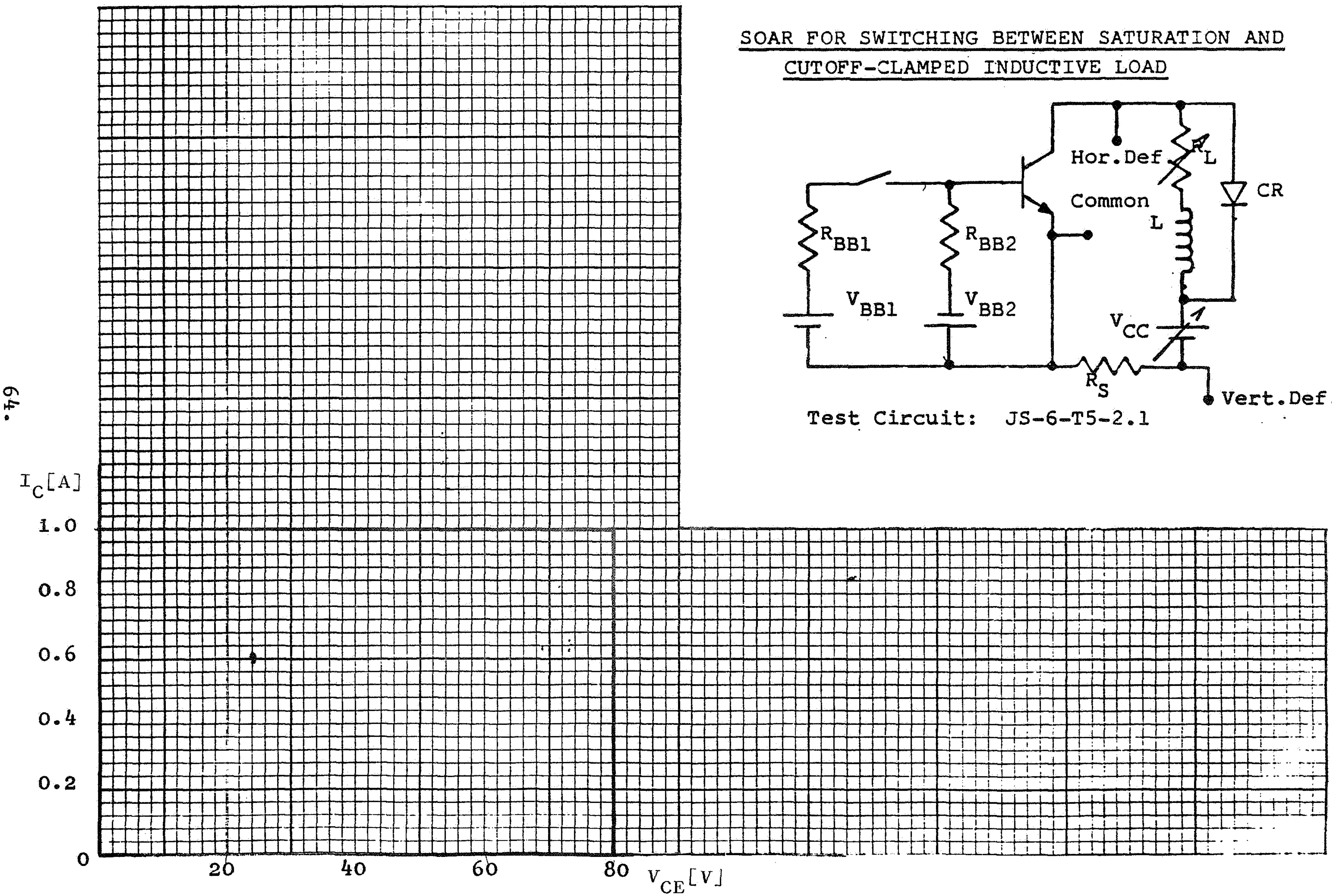


Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

Figure 4

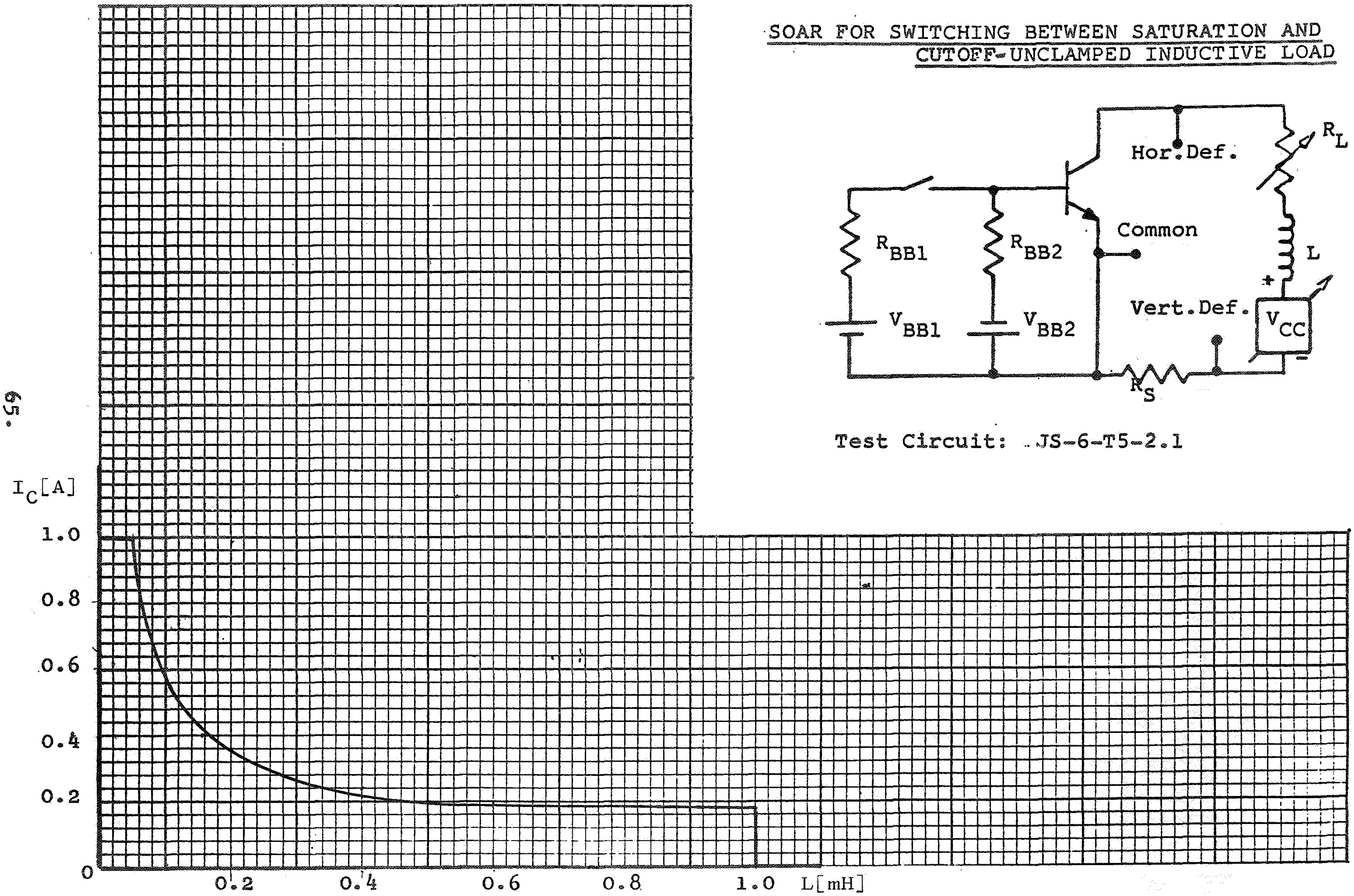

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD
R_L
Hor. Def.
R_{BB1}
R_{BB2}
Common
L
+
Vert. Def.
V_{BB1}
V_{BB2}
V_{CC}
R_S
Test Circuit: JS-6-T5-2.1
I_C[A]
1.0
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
1.0
L[mH]

Figure 5

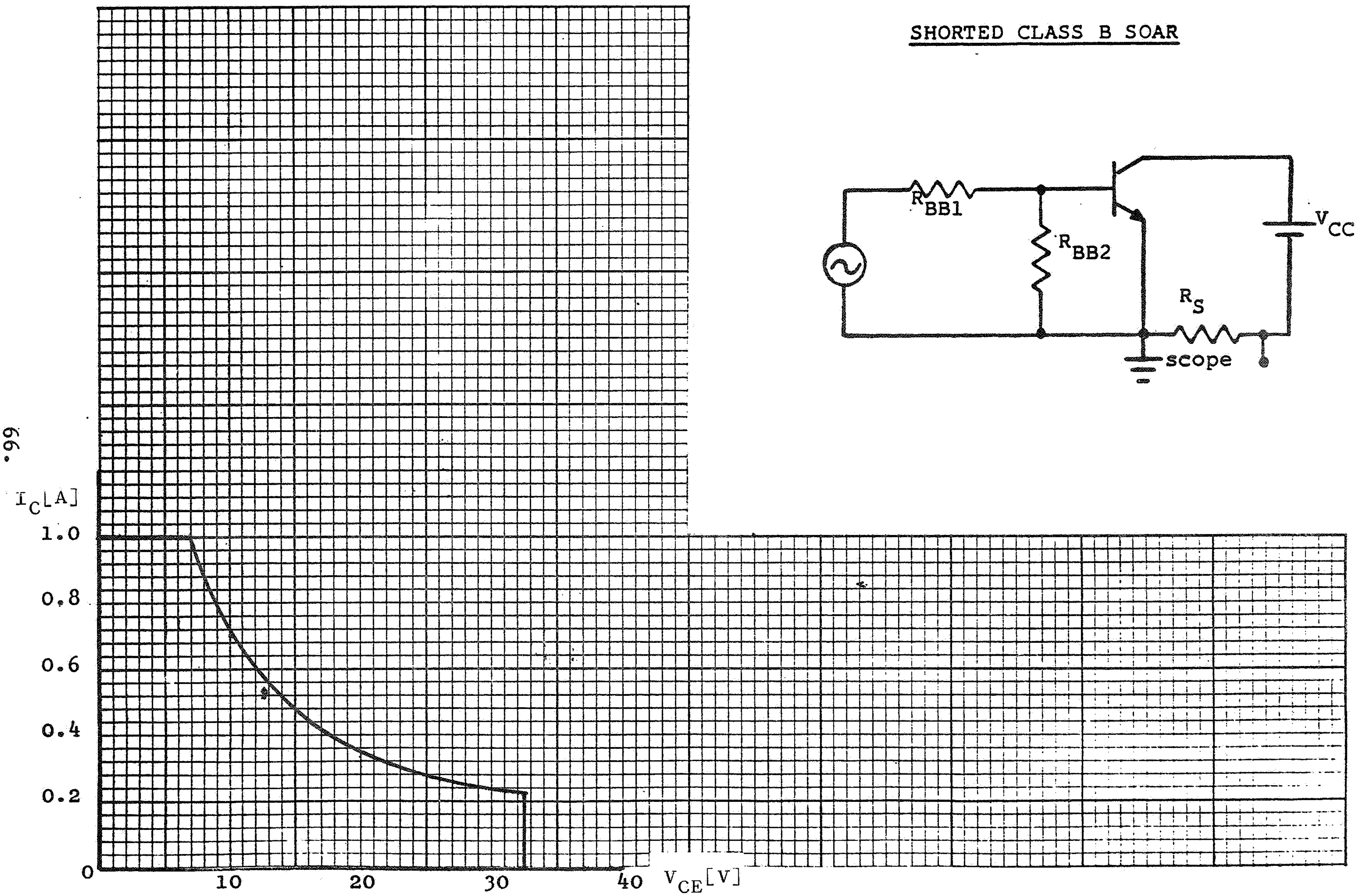

SHORTED CLASS B SOAR
R BB1
R BB2
V CC
R S
scope
I C [A]
1.0
0.8
0.6
0.4
0.2
0
10
20
30
40
V CE [V]

Figure 6

SILICON POWER TRANSISTOR

< S2N2034A >

SAFE OPERATING AREA DETERMINATION FOR PREVENTION OF SECOND BREAKDOWN

-- Manufacturer H --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item		Test Methods and Test Conditions
1.0.0	General Description	
1.1.0	Type - NPN	
1.2.0	Material - Silicon	
2.0.0	Mechanical Data	
2.1.0	Outline - TO5	
2.2.0	Terminal Designation	
	1. -- Emitter	
	2. -- Base	
	3. -- Collector	
	case -- Collector	
3.0.0	Maximum Ratings	
3.1.0	Temperature	
3.1.1	$T_{STG(max)} = +200^{o}C$	JS-6-T1.2 [JEDEC Publication No.65 "Test Procedures for Verification of Maximum Ratings."]
	$T_{STG(min)} = -65^{o}C$	JS-6-T1.1
3.1.2	$T_{J(max)} = 200^{o}C$	JS-6-T2
		$T_C = 100^{o}C$
		$V_{CB} = 60V$, $I_C = 83mA$
3.1.3	T (Lead) = $230^{o}C$	Distance from case - 1/16 in.
		Time = 3.0s
3.2.0	Voltage	$T_C = 25^{o}C$
3.2.1	$V_{CBO} = 80V$	JS-6-T3 or MIL-STD-750A Method 3001.1

Item		Test Method and Test Conditions
3.2.2	$V_{EBO} = 10V$	JS-6-T4 or MIL-STD-750A Method 3026.1
3.2.3	$V_{CEX} = 60V$	JS-6-T5.1 I_C ($V_{CE} = V_{CEX}$) = 3A $V_{CC} = 60V$, $R_L = 19.6\Omega$ L = 1.0mH*, CR = 1N1202 $V_{BB1} = 6V$, $R_{BB1} = 5\Omega$ $V_{BB2} = 1.5V$, $R_{BB2} = 5\Omega$ Pulse width = 1.0ms, Duty Cycle = 2% $R_S = 0.1\Omega$, $t_r \leq 50\mu s$ $t_f \leq 50$ us *Miller # 7871 in series with 7825-3
3.3.0	Current	
3.3.1	$I_C = 3A$	JS-6-T6 $I_B = 0.6A$, $T_C = \leq 25^oC$
3.3.2	$I_B = 1A$	JS-6-T8 $T_C = \leq 25^oC$
3.4.0	Power	
3.4.1	$P_T = 5W$	JS-6-T12 $T_C = \leq 100^oC$ $V_{CB} = 60V$, $I_C = 83mA$
	Derating Factor = 0.05 W/^{o}C	
3.4.2	$P_{TM} = I_C\ V_{CC} = 180W$	JS-6-T13 $T_C = 100^oC$, $V_{CC} = 60V$, $V_{BB} = 1.5V$, $R_{BB} = 5\Omega$

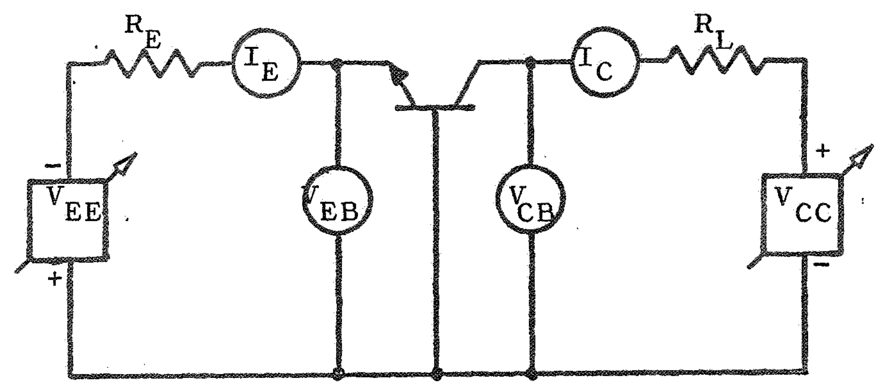
Item		Test Methods and Test Conditions
3.4.2	(Cont'd)	Pulse width = 1ms, Duty Cycle = $\leq 1\%$, $t_r \leq 50\mu s$, $t_f = \leq 50\mu s$
3.5.0	Maximum Operating Conditions	
3.5.1	Forward Biased Continuous DC-SOAR	JS-6-T12 [See Figure 1] Test Point: [See 3.4.1]
3.5.2	Pulsed Forward Biased SOAR	JS-6-T14 [See Figure 2] Test Points: $T_C \leq 100^oC$, $V_{BB} = 1.5V$, $R_{BB} = 5\Omega$ $t_r \leq 50\mu s$, $t_f \leq 50\mu s$, $I_C = 3A$ Duty Cycle $\leq 1\%$, $R_S = 0.1\Omega$ 1. For $t_p = 7.5ms$; $V_{CC} = 20V$ 2. For $t_p = 5.0ms$; $V_{CC} = 30V$ 3. For $t_p = 2.5ms$; $V_{CC} = 50V$ 4. For $t_p = 1ms$; $V_{CC} = 60V$
3.6.0	SOAR Switching between Saturation and Cutoff	
3.6.1	Resistive Load	JS-6-T5-5.1 with L=0 and CR disconnected [See Figure 3] Test Points: $I_C = 3A$, $V_{CC} = 90V$, $R_{BB1} = 5\Omega$ $R_{BB2} = 5\Omega$, $V_{BB1} = 6V$, $V_{BB2} = 1.5V$ $T_C = 100^oC$; $t_f \leq 50\mu s$, Collector Current

Item		Test Methods and Test Conditions
3.6.1	(Cont'd)	$t_r \leq 50\mu s$ Collector Current $R_S = .1\Omega$
3.6.2	Clamped Inductive Load	JS-6-T5-5.1 [See Figure 4] Test Points: $I_C = 3A$, $V_{CC} = 60V$, $R_L = 19.6\Omega$ $L = 1mH*$, $R_{BB1} = 5\Omega$, $R_{BB2} = 5\Omega$ $V_{BB1} = 6V$, $V_{BB2} = 1.5V$, $t_p = 1ms$ CR = 1N1202, $T_C = 25^oC$, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$ Duty Cycle = 2%, $R_S = 0.1\Omega$ *Miller # 7871 in series with 7825-3
3.6.3	Unclamped Inductive Load	JS-6-T5-5.1 with CR disconnected [See Figure 5] Test Points: $R_{BB1} = 5\Omega$, $R_{BB2} = 5\Omega$, $R_S = .1\Omega$ $V_{BB1} = 6V$, $V_{BB2} = 1.5V$, $f = 20Hz$ $T_C = 25^oC$, $d = 10\%$ 1. $I_C = 3A$, $V_{CC} = 50V$, $R_L = 16.23\Omega$ $L = 15mH*$ 2. $I_C = 0.9A$, $V_{CC} = 35V$, $R_L = 38.5\Omega$ $L = 60mH**$ *Series Stancor C-2688 & C-2689 **Series 2 Stancor C-2686 & C-2688
3.7.0	Shorted Class B SOAR	[See Figure 6] Test Point: $I_{C(peak)} = 0.25A$, $V_{CC} = 60V$, $R_S = .1\Omega$ $R_{BB1} = 1\Omega$, $R_{BB2} = 3\Omega$, $f = 20Hz$ $T_C \leq 100^oC$

Item		Test Methods and Test Conditions
4.0.0	**Electrical Characteristic**	
	Maximum limits unless otherwise noted.	$T_C = 25^oC$ [unless otherwise noted]
	Technique:	
	DC - Continuous Operation	
	C.T. - Curve Tracer	
	P - 300µs Pulse 2% Duty Cycle	
4.1.0	Static	
4.1.1	$I_{CEX} = 750\mu A$	$V_{CE} = 80V$, $V_{BE} = -1.5V$, $T_C = 150^oC$ Technique - C.T.
4.1.2	$I_{CEX} = 150\mu A$	$V_{CE} = 80V$, $V_{BE} = -1.5V$ Technique - C.T.
4.1.3	$I_{CBO} = 150\mu A$	$V_{CB} = 80V$ Technique - C.T.
4.1.4	$I_{EBO} = 50\mu A$	$V_{EB} = 10V$ Technique - C.T.
4.1.5	$V_{[BR]CEO} = 60V$ min	$I_C = 50mA$ Technique - C.T.
4.1.6	$I_{CEO} = 100\mu A$	$V_{CE} = 45V$ Technique - C.T.
4.1.7	$h_{FE} = 20$ min $h_{FE} = 60$ max	$V_{CE} = 4V$, $I_C = 1A$ Technique - C.T.
4.1.8	$h_{FE} = 20$ min	$V_{CE} = 4V$, $I_C = 1A$, $T_C = -55^oC$ Technique - C.T.

Item		Test Methods and Test Conditions
4.1.9	$V_{CE[sat]} = 0.3V$	$I_C = 1A$, $I_B = 0.1A$ Technique - C.T.
4.1.10	$V_{BE} = 1.2V$	$V_{CE} = 4$; $I_C = 1A$ Technique - C.T.
4.1.11	$V_{CE[sat]} = 1V$	$I_C = 3A$, $I_B = 0.3A$
4.1.12	$V_{BE[sat]} = 1.5V$	$I_C = 3A$, $I_B = 0.3A$ Technique - C.T.
4.2.4	$t_{on} = 1.0\mu s$	$V_{CC} = 12V$, $I_C = 1.0A$, $I_{B1} = 100mA$
4.2.5	$t_{off} = 1.5\mu s$	$V_{CC} = 12V$, $I_C = 1.0A$, $I_{B1} = 100mA$, $I_{B2} = -50mA$
4.2.7	$\lvert h_{fe} \rvert min = 1$ $\lvert h_{fe} \rvert max = 6$	$V_{CE} = 4V$, $I_C = 0.1A$ $f = 1.0MHz$
5.0.0	Thermal Characteristics	
5.1.0	$\tau_J = 80ms$ min	$I_C = 1A$, $V_{CE} = 5V$, $T_C = 25^{\circ}C$ MIL-STD-750 Method 3146.1
5.2.0	$\theta_{J-C} = 20^{\circ}C/W$	$I_C = 1A$, $V_{CE} = 5V$ MIL-STD-750A Method 3136

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^oC$, $I_C \geq I_{CEO}$

Test Circuit: JS-6-T12

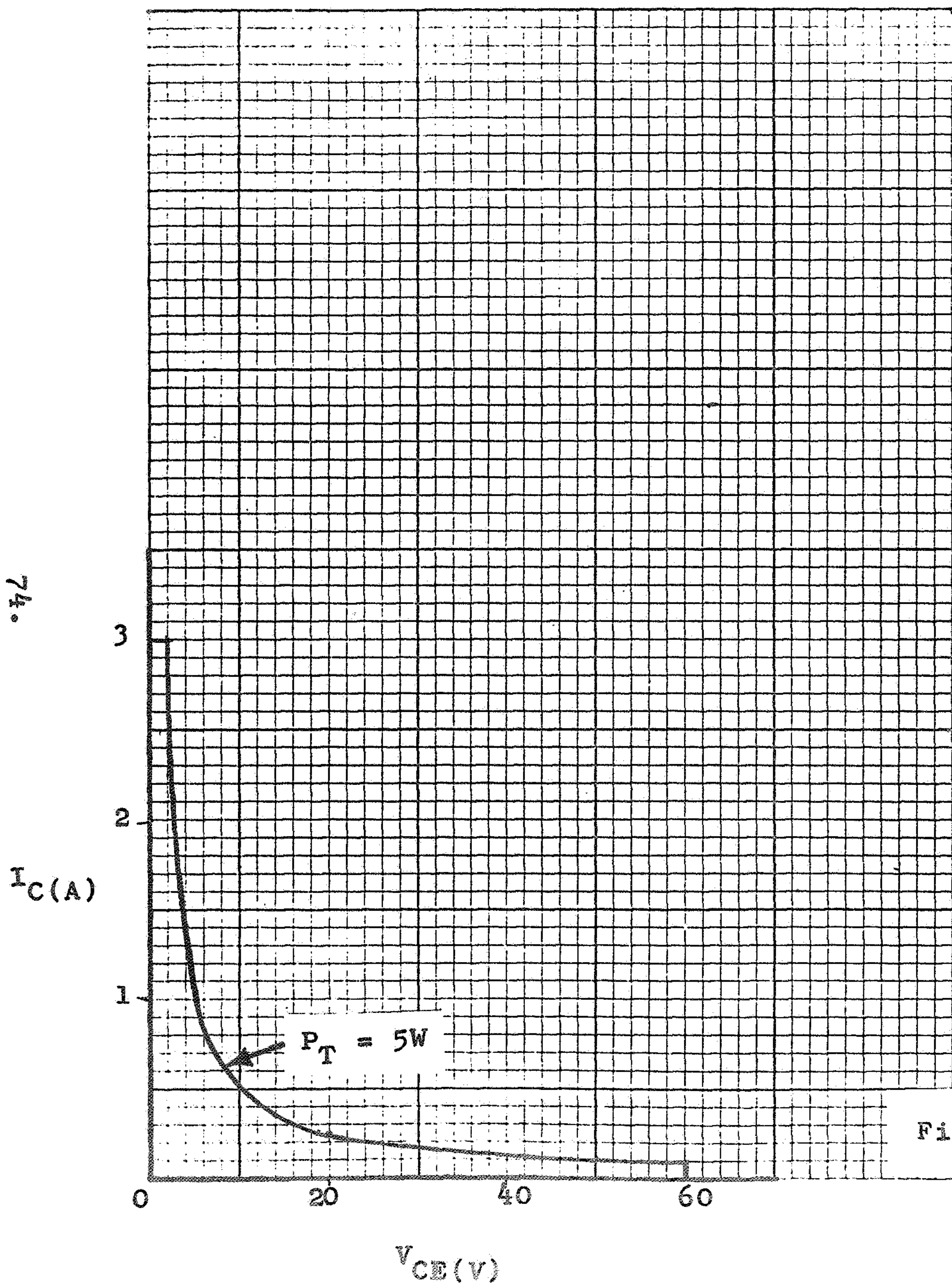


Figure 1

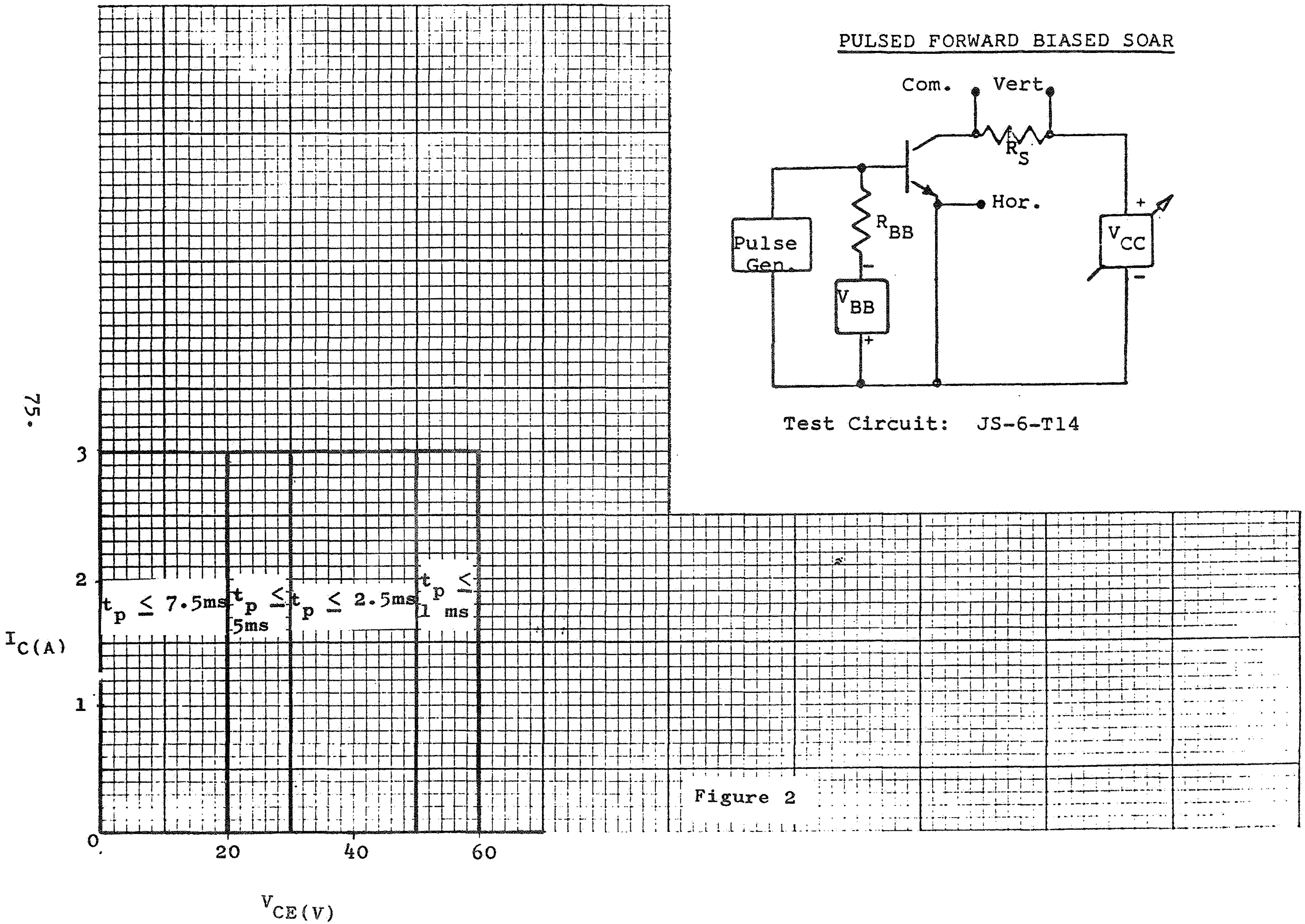
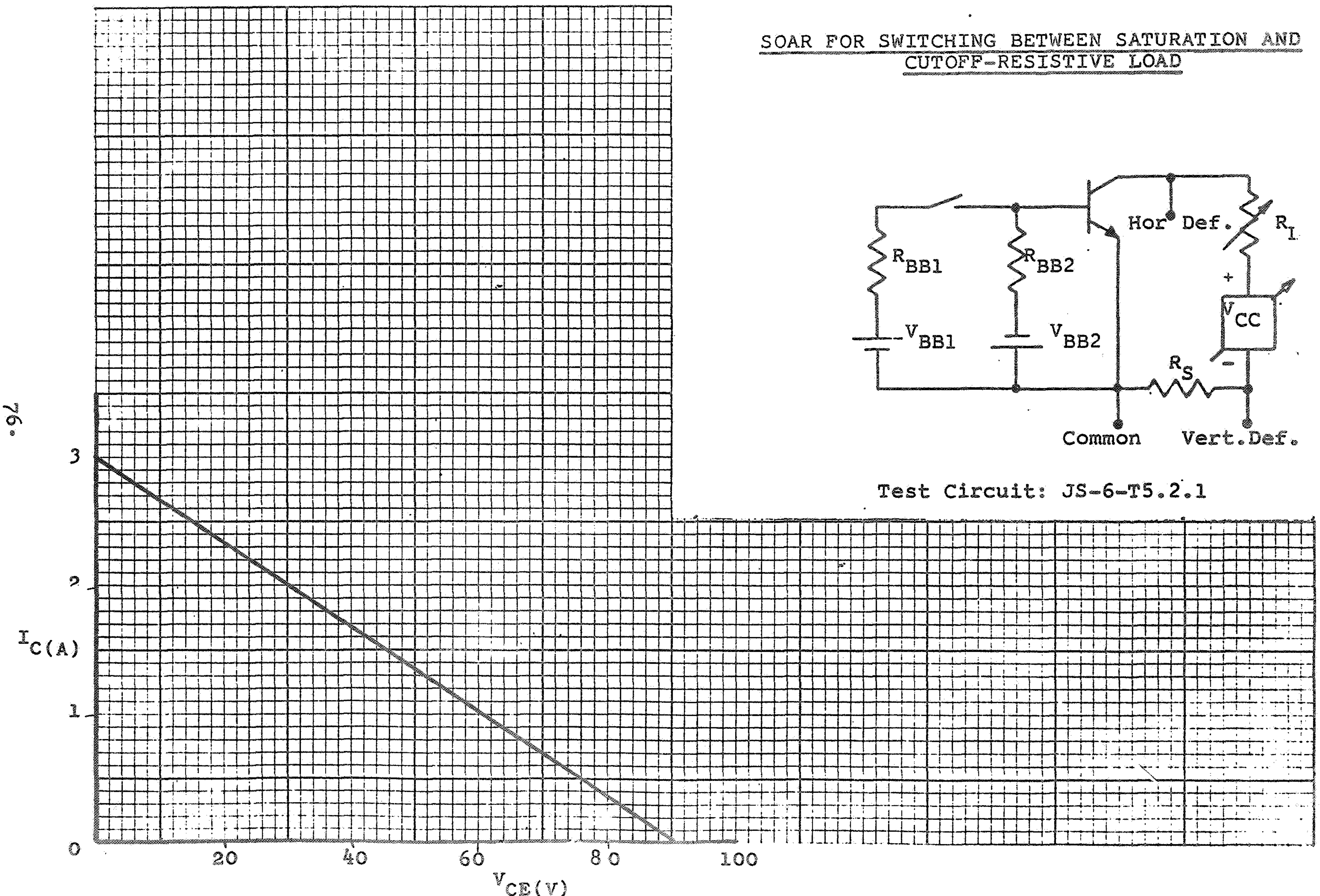

PULSED FORWARD BIASED SOAR
Com.
Vert.
R_S
Hor.
R_{BB}
Pulse Gen.
V_{BB}
V_{CC}
Test Circuit: JS-6-T14
3
2
1
0
20
40
60
$I_{C(A)}$
$V_{CE(V)}$
$t_p \leq 7.5ms$
$t_p \leq 5ms$
$t_p \leq 2.5ms$
$t_p \leq 1\ ms$

Figure 2

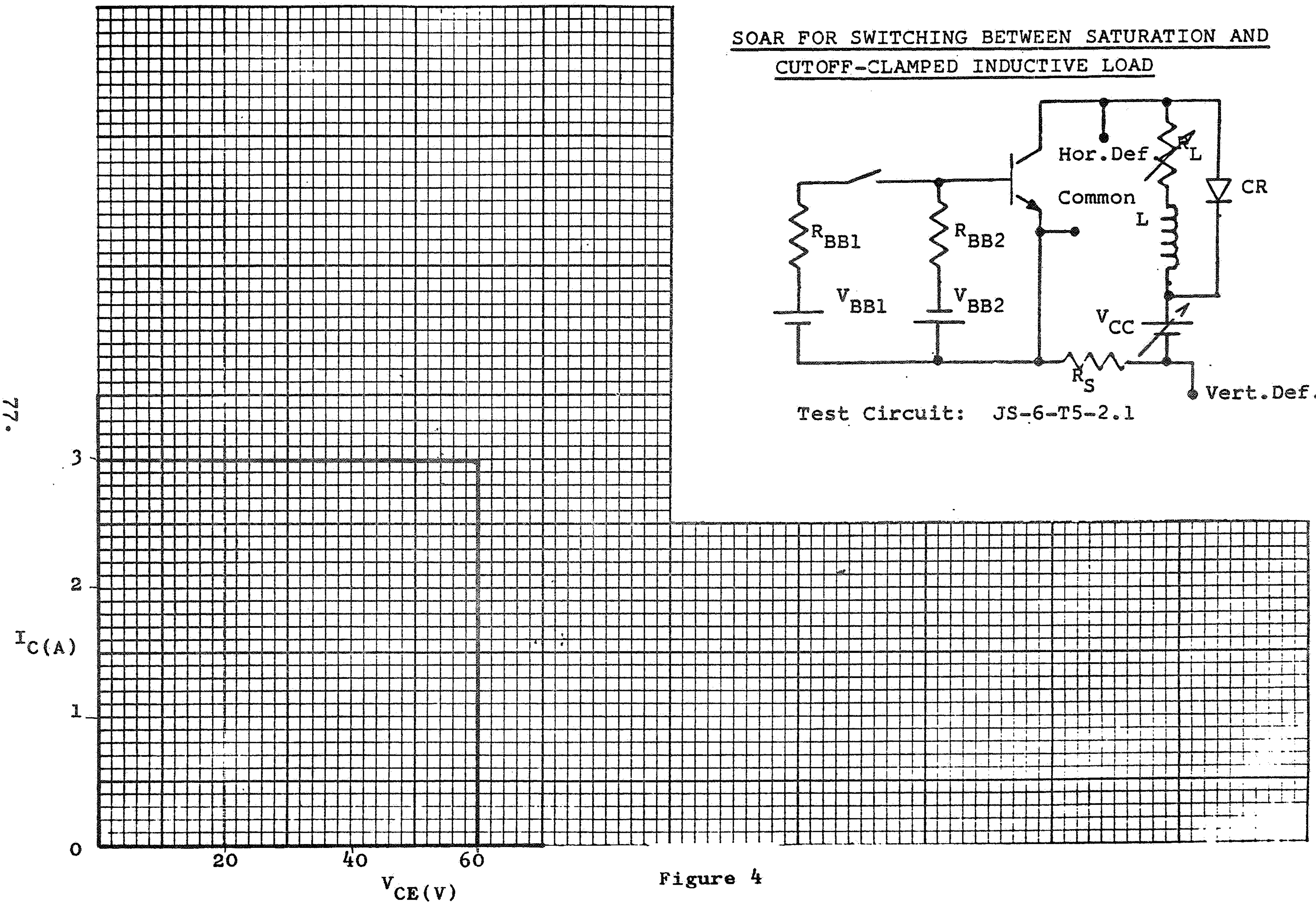
SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD



Test Circuit: JS-6-T5.2.1

Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

Figure 4

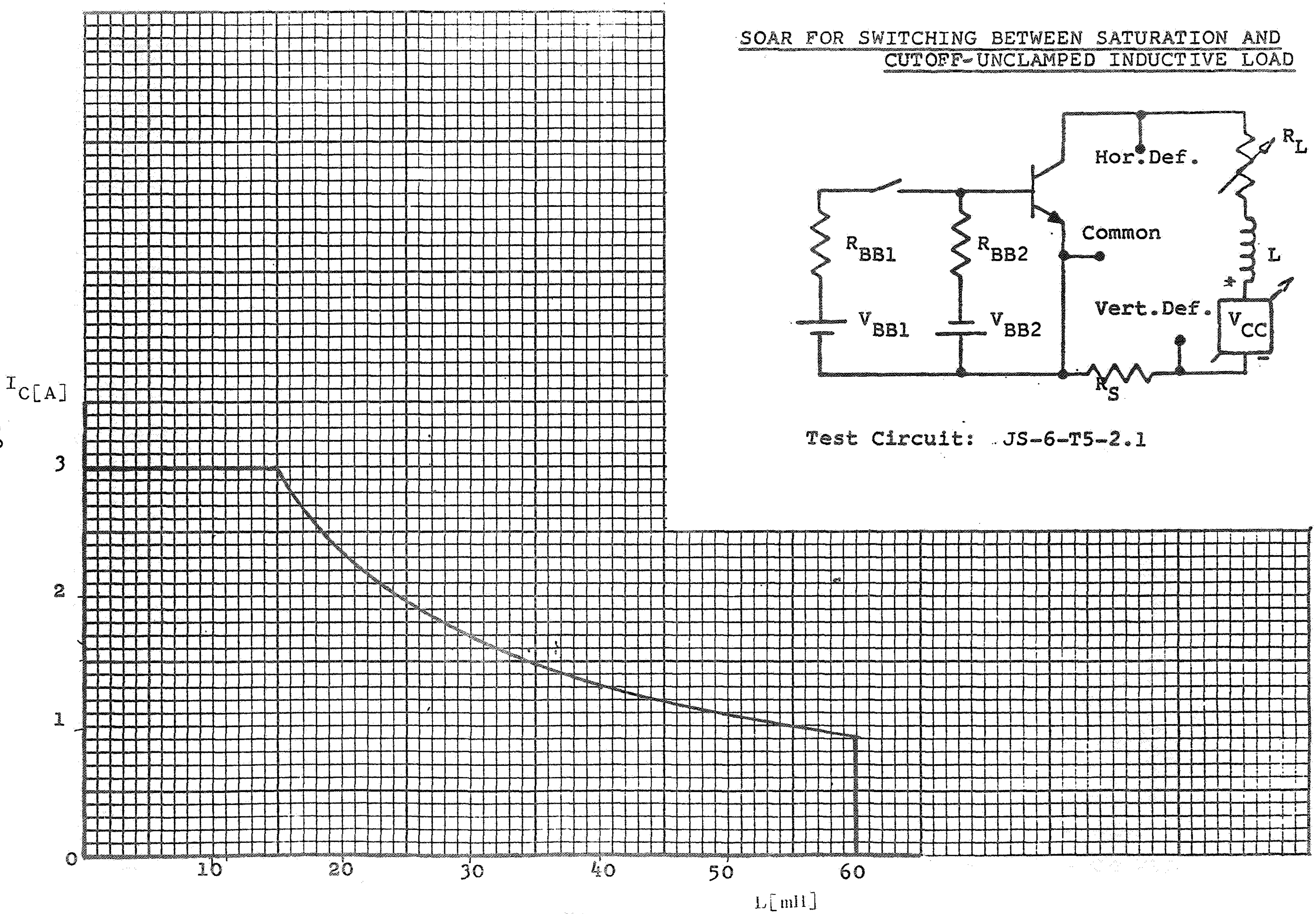

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD
R_L
Hor. Def.
Common
L
Vert. Def.
V_{CC}
R_{BB1}
R_{BB2}
V_{BB1}
V_{BB2}
R_S
Test Circuit: JS-6-T5-2.1
I_C[A]
0
1
2
3
10
20
30
40
50
60
L[mH]

Figure 5

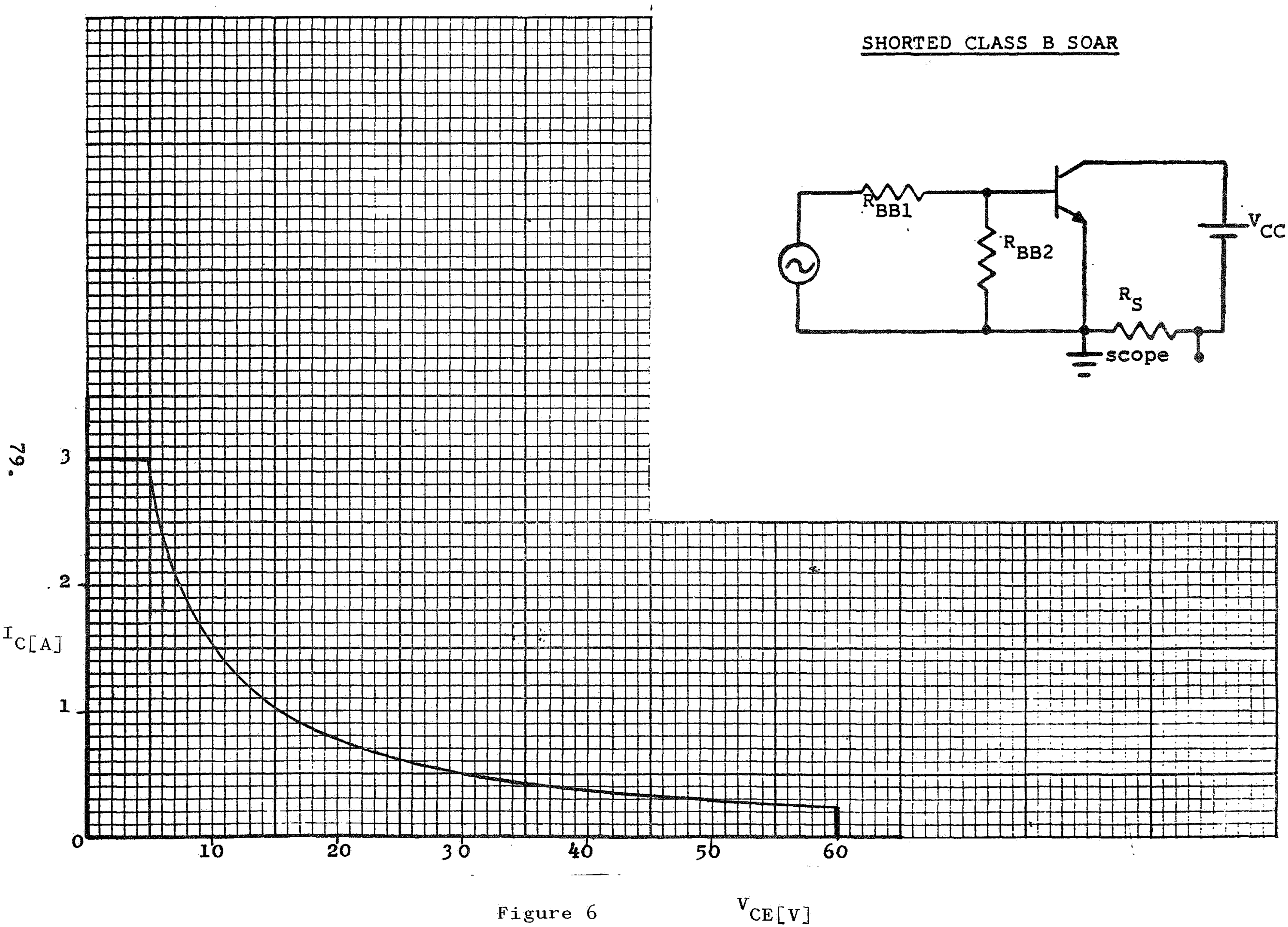

SHORTED CLASS B SOAR
R_{BB1}
R_{BB2}
V_{CC}
R_S
scope
3
2
1
0
$I_{C[A]}$
10
20
30
40
50
60
$V_{CE[V]}$

Figure 6

Silicon Power Transistor

< Type 2N2126 >

SAFE OPERATING AREA DETERMINATION FOR PREVENTION OF SECOND BREAKDOWN

-- Manufacturer C --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

Contract No. NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item		Test Methods and Test Conditions
1.0.0	General Description	
1.1.0	Type - NPN	
1.2.0	Material - Silicon	
2.0.0	Terminal Designation	
	1 - Base	
	2 - Emitter	
	3 - Collector	
	case - Collector	
2.2.1	Maximum Stud Torque - 100 in.lbs.	
3.0.0	Maximum Ratings	
3.1.0	Temperature	
3.1.1	$T_{stg}(max) = +175^{\circ}C$	JS-6-T1.1
	$T_{stg}(min) = -65^{\circ}C$	JS-6-T1.2
3.1.2	$T_j = 175^{\circ}C$	JS-6-T2 $T_C = 100^{\circ}C$, $V_{CB} = 100V$, $I_C = 1.67A$
3.1.3	$T(Lead) = 230^{\circ}C$	Distance from case - 1/4 in., Time - 10s
3.2.0	Voltage	
3.2.1	$V_{CBO} = 200V$	JS-5-T3 or MIL-STD-750A Method 3001.1 (See page 18)
3.2.2	$V_{EBO} = 15V$	JS-6-T4 or MIL-STD-750A Method 3026.1 (See page 19)
3.2.3	$V_{CEX} = 180V$	JS-6-T5-2.1 $I_C(V_{CE} = V_{CEX}) = 30A$, $V_{CC} = 180V$, $R_L = 6\Omega$, $L = 1mH$*, CR - 1N1204, $V_{BB1} = 14V$, $R_{BB1} = 1\Omega$, $V_{BB2} = 8V$, $R_{BB2} = 3\Omega$, Duty Cycle = 1%, $t_p = 1ms$, $R_s = 0.1\Omega$ *Miller No. 7870

Item		Test Methods and Test Conditions
3.3.0	Current	
3.3.1	I_C = 30A	JS-6-T6 I_b = 6A, T_C = 25°C
3.3.2	I_B = 10A	JS-6-T8 T_C = 25°C
3.3.3	I_E = 36A	JS-6-T10 I_b = 6A, T_C = 25°C
3.4.0	Power	
3.4.1	P_T = 167W	JS-6-T12 T_C = 100°C, V_{CB} = 175V, I_C = .93A Derating Factor - 2.22W/°C
3.4.2	$P_{TM} = I_C\ V_{CC}$ = 465W	JS-6-T13 T_C = 100°C, V_{CC} = 155V, V_{BB} = 8V, R_{BB} = 3Ω, I_C = 30A, Pulse Width = 100µs Duty Cycle = 1%, $t_r \leq 50\mu s$, $t_f = 50\mu s$
3.5.0	Maximum Operating Conditions	
3.5.1	Forward Biased Continuous DC-SOAR	JS-6-T12 Test Point: (See 3.4.1)
3.5.2	Pulsed Forward Biased SOAR	JS-6-T14 Test Points: T_C = 100°C, V_{BB} = 8V, R_{BB} = 3Ω $t_r \leqq 50\mu s$, $t_f \leqq 50\mu s$, I_C = 30A, Duty Cycle $\leqq$ 1%, R_S = 0.1Ω 1. For t_p = 10ms; V_{CC} = 50V 2. For t_p = 1ms: V_{CC} = 90 3. For t_p = 500µs: V_{CC} = 120V 4. For t_p = 100µs: V_{CC} = 155V

Item		Test Methods and Test Conditions
3.6.0	SOAR Switching between Saturation and Cutoff	
3.6.1	Resistive Load	JS-6-T5-2.1 with L = 0 and CR Disconnected Test Points: $R_{BB1} = 1\Omega$, $R_{BB2} = 3\Omega$, $V_{BB1} = 14V$, $V_{BB2} = 8V$, $T_C = 100^oC$, $t_f \leqq 50\mu s$ Coll. Current, $t_r \leqq 50\mu s$ Coll. Current, $R_S = 0.1\Omega$, $I_C = 30A$, $V_{CC} = 200V$
3.6.2	Clamped Inductive Load	JS-6-T5-2.1 Test Points: (See 3.2.3)
3.6.3	Unclamped Inductive Load	JS-6-T5-2.1 and CR disconnected Test Points: 1. $V_{BB1} = 14V$ $L = 0.2mH$* $R_{BB1} = 1\Omega$ $R_L = 0.4\Omega$ $V_{BB2} = 8V$ $V_{CC} = 16.5V$ $R_{BB2} = 3\Omega$ $f = 60Hz$ $R_S = 0.1\Omega$ $d = 10\%$ 2. $V_{BB1} = 7V$ $L = 1mH$** $R_{BB1} = 1\Omega$ $R_L = 2.1\Omega$ $V_{BB2} = 8V$ $V_{CC} = 10.5V$ $R_{BB2} = 3\Omega$ $f = 60Hz$ $R_S = 0.1\Omega$ $d = 10\%$ *Miller No. 7828 **Miller No. 7830 in series with 7871

Item		Test Methods and Test Conditions
3.7.0	Shorted Class B SOAR	[See Figure 6] Test Points: $I_{Cpeak} = 5.4A$, $V_{CC} = 92.5V$, $R_S = 0.1\Omega$ $R_{BB1} = 1\Omega$, $R_{BB2} = 3\Omega$, $f = 20Hz$, $T_C = 100^oC$
4.0.0	Electrical Characterisitics Maximum limits unless otherwise noted Technique: DC - Continuous Operation C.T. - Curve Tracer P - 300µs Pulse, 2% Duty Cycle	$T_C = 25^oC$ [unless otherwise noted]
4.1.0	Static	
4.1.1	$I_{CEX} = 30mA$	$V_{CEX} = 200V$, $V_{BE} = -1.5V$, Technique - C.T., $T_C = 175^oC$
4.1.2	$I_{CEO} = 100mA$	$V_{CEO} = 175V$, Technique - C.T.
4.1.3	$I_{EBO} = 25mA$	$V_{EBO} = 15V$, $T_C = 175^oC$ Technique - C.T.
4.1.4	$V_{CEO} = 185V$ min	JS-6-T5-2.1 and CR disconnected $I_C = 5A$, $R_{BB1} = 3\Omega$, $V_{BB1} = 3V$, $R_{BB2} = \infty\Omega$, $d = 50\%$, $f = 60Hz$, $L = 5mH$, $R_L = 0.1\Omega$, $R_S = 0.1\Omega$ Adjust V_{CC} for specified I_C
4.1.5	$h_{FE} = 10$ min	$V_{CE} = 4V$, $I_C = 20A$ Technique-C.T.
4.1.6	$V_{CE(sat)} = 1.5V$	$I_C = 20A$, $I_B = 4A$, Technique - C.T.
4.1.7	$V_{BE(sat)} = 2.5V$	$I_C = 20A$, $I_B = 4A$, Technique - C.T.

Item		Test Methods and Test Conditions
4.2.0	Dynamic	
4.2.1	t_{on} = 20μs	V_{CC} = 12V, I_C = 20A, I_{B1} = 5A
4.2.2	t_{off} = 25μs	V_{CC} = 12V, I_C = 20A, I_{B2} = 5A
4.2.3	f_{hfe} = 8KHz min 32KHz max	I_C = 5A, V_{CE} = 12V
5.0.0	Thermal Characteristics	
5.1.0	T_{jmin} = 45ms	I_C = 2A, V_{CE} = 10V, T_C = 25°C MIL-STD-750, Method 3146.1
5.2.0	Θ_{JC} = 0.45°C/W	I_C = 2A, V_{CB} = 10V MIL-STD-750A, Method 3136

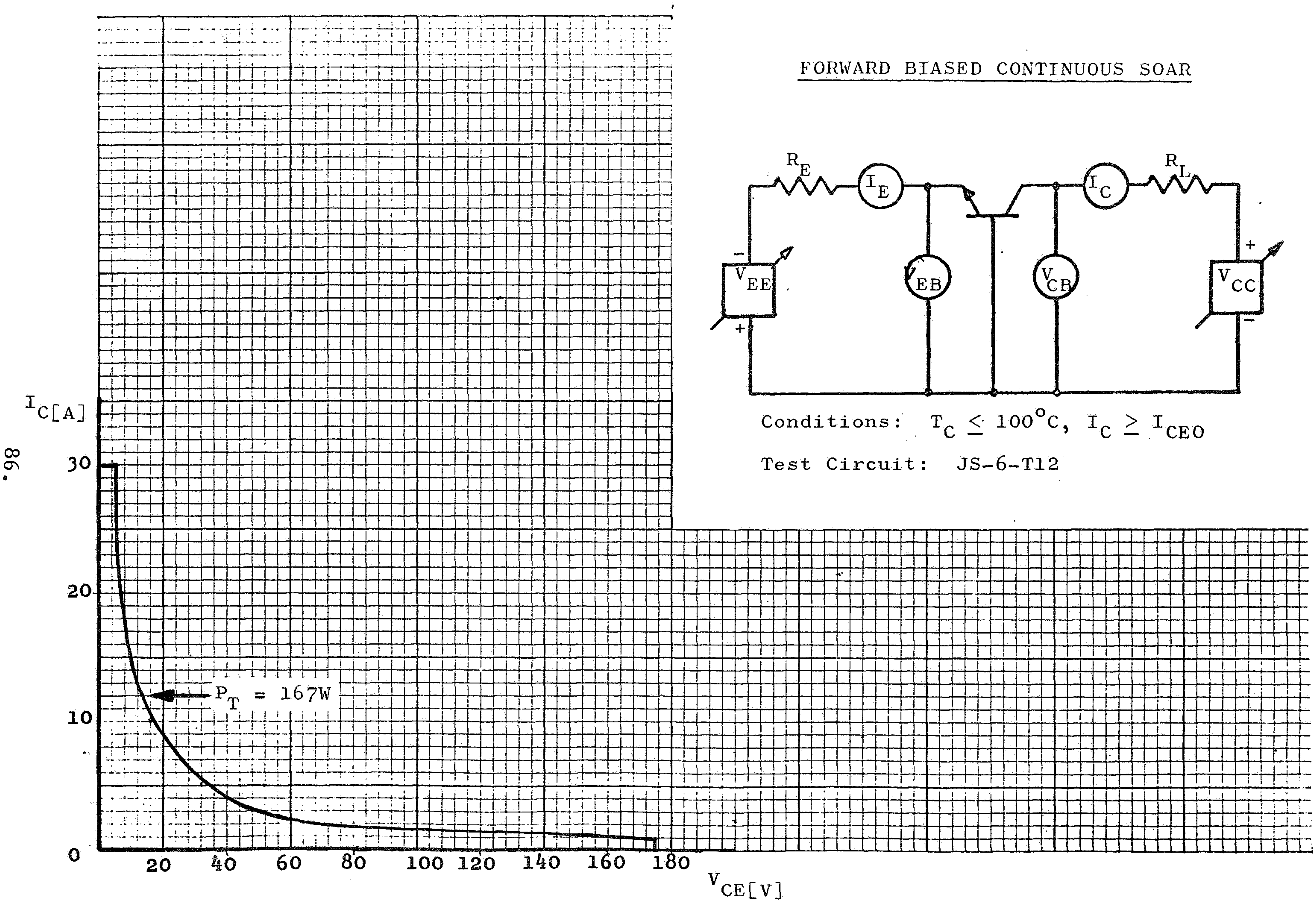

FORWARD BIASED CONTINUOUS SOAR
R_E
I_E
V_{EE}
V_{EB}
V_{CB}
I_C
R_L
V_{CC}
Conditions: $T_C \leq 100^{\circ}C$, $I_C \geq I_{CEO}$
Test Circuit: JS-6-T12
$I_{C[A]}$
30
20
10
0
P_T = 167W
20
40
60
80
100
120
140
160
180
$V_{CE[V]}$

Figure 1

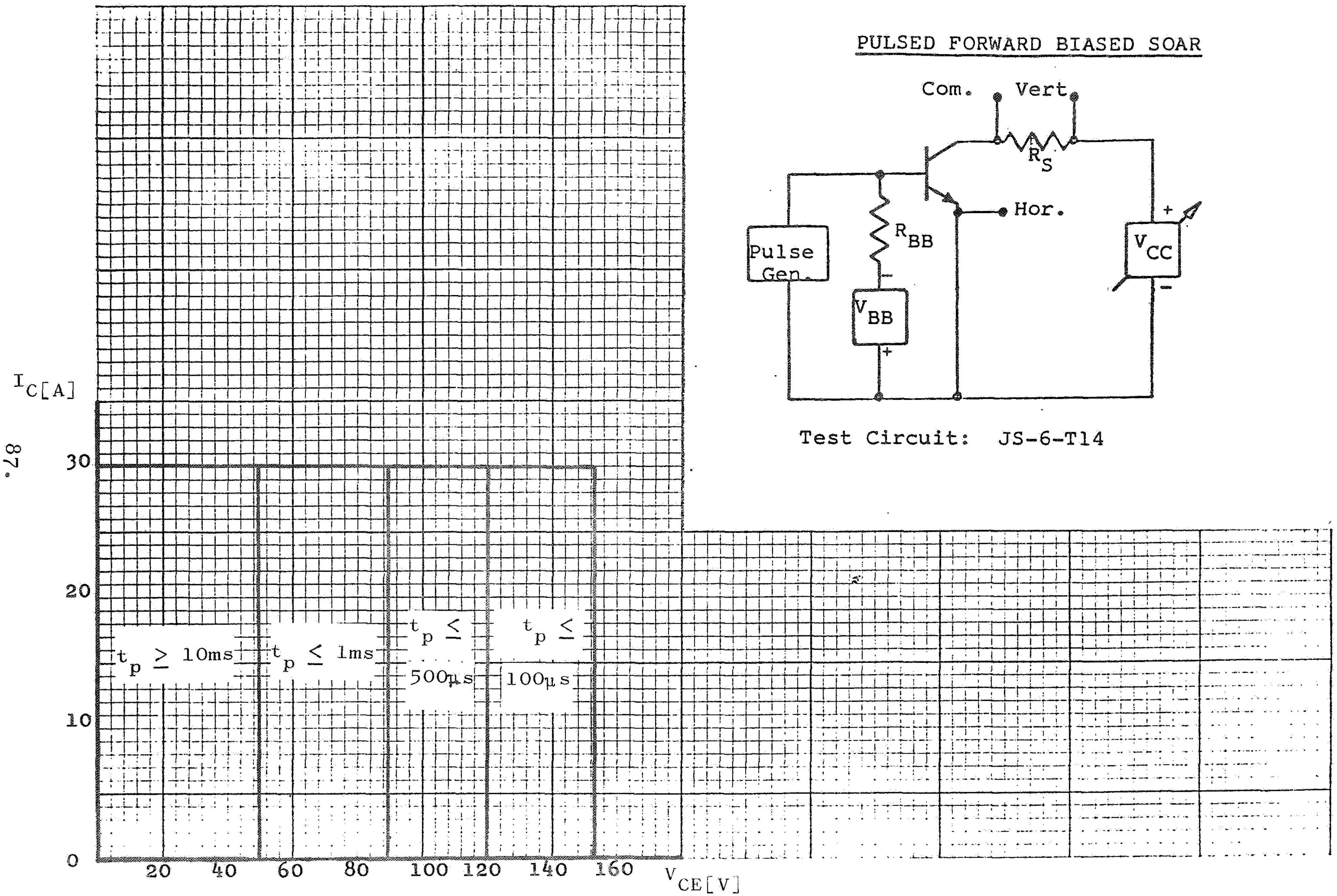
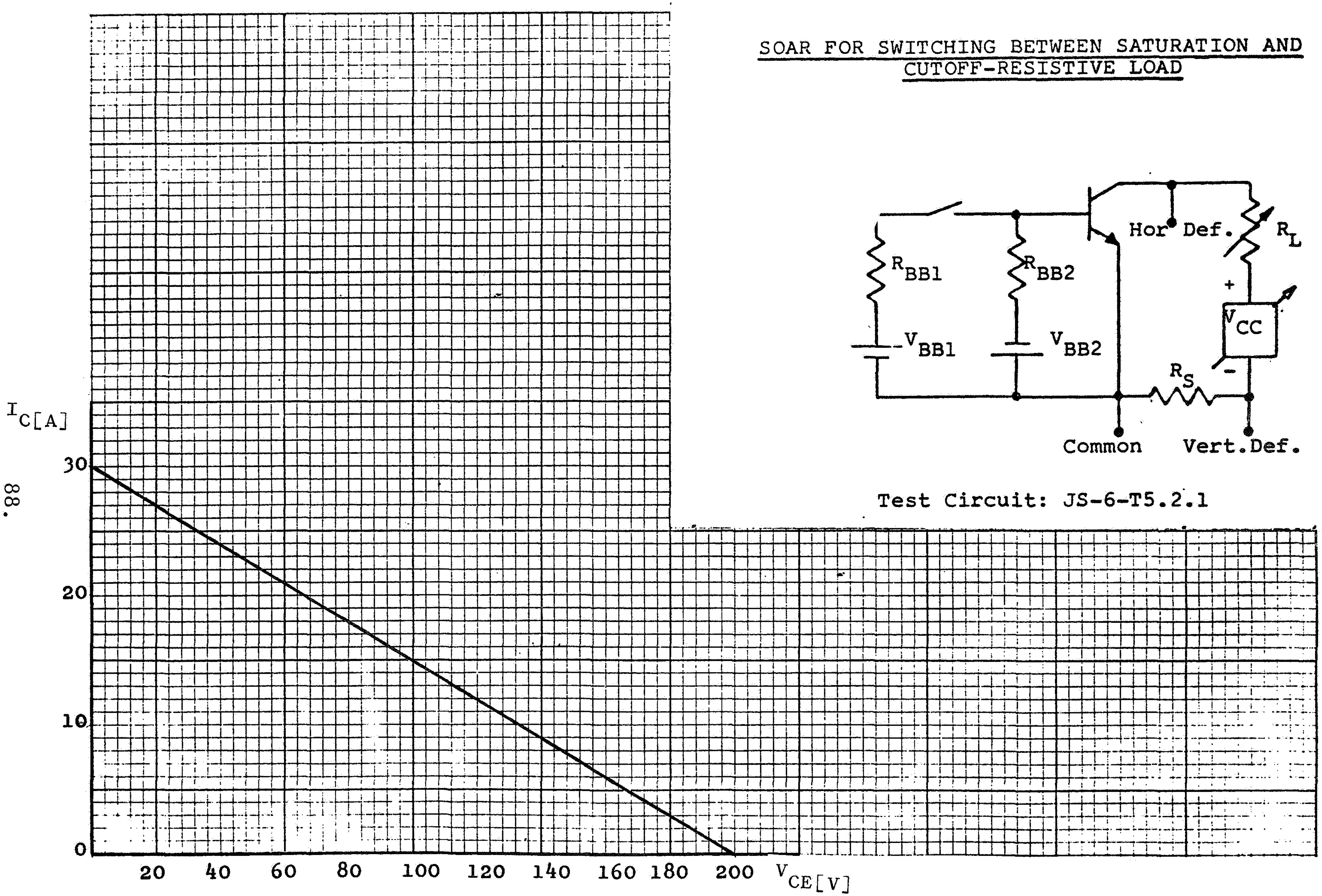

PULSED FORWARD BIASED SOAR
Com.
Vert
R_S
Hor.
Pulse Gen.
R_{BB}
V_{BB}
V_{CC}
Test Circuit: JS-6-T14
$I_{C[A]}$
30
20
10
0
20
40
60
80
100
120
140
160
$V_{CE[V]}$
$t_p \geq 10ms$
$t_p \leq 1ms$
$t_p \leq 500\mu s$
$t_p \leq 100\mu s$

Figure 2



SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

Test Circuit: JS-6-T5.2.1

Figure 3

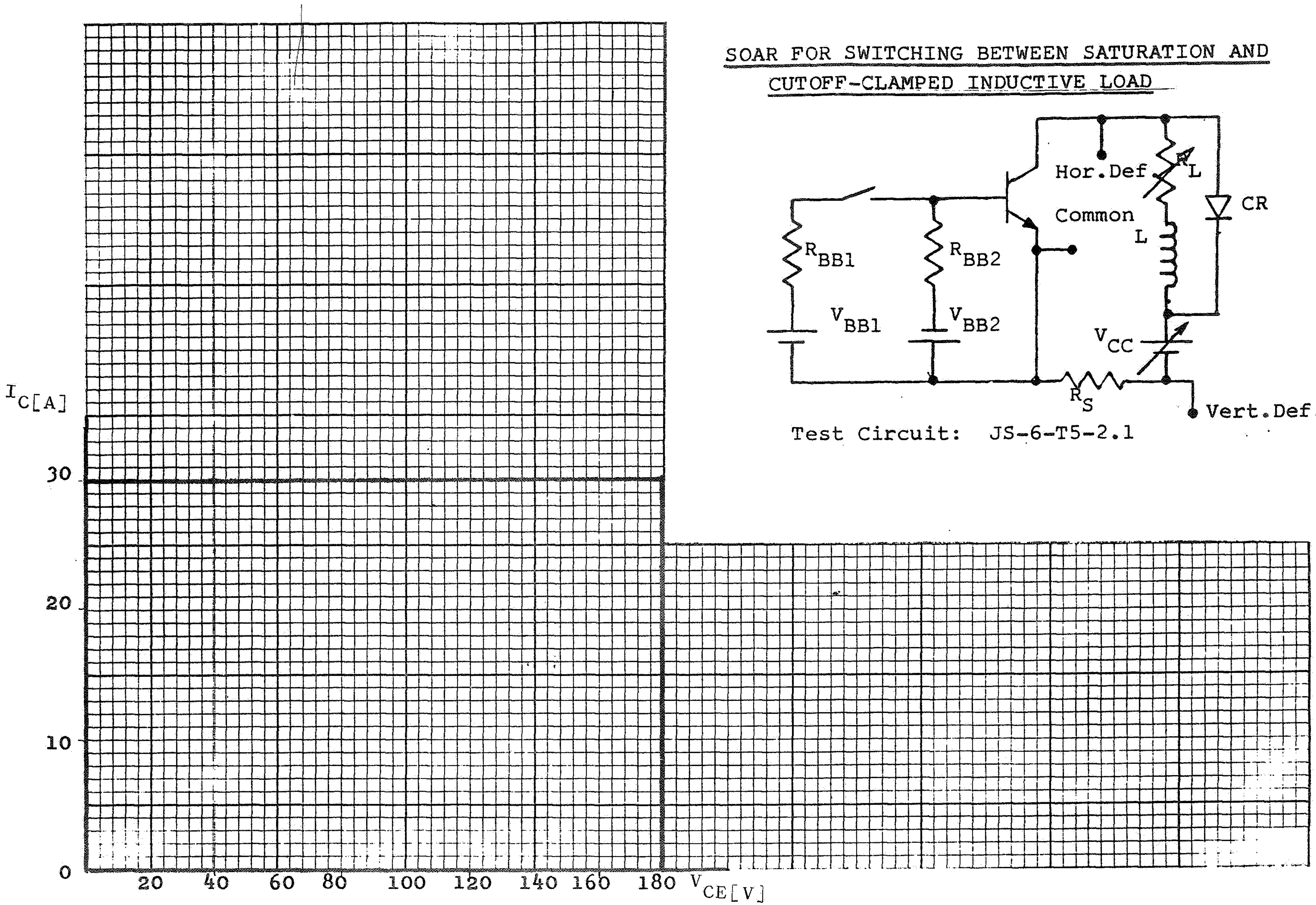

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-CLAMPED INDUCTIVE LOAD
Hor.Def
R L
CR
Common
L
R BB1
R BB2
V BB1
V BB2
V CC
R S
Vert.Def.
Test Circuit: JS-6-T5-2.1
I C[A]
30
20
10
0
20
40
60
80
100
120
140
160
180
V CE[V]

Figure 4

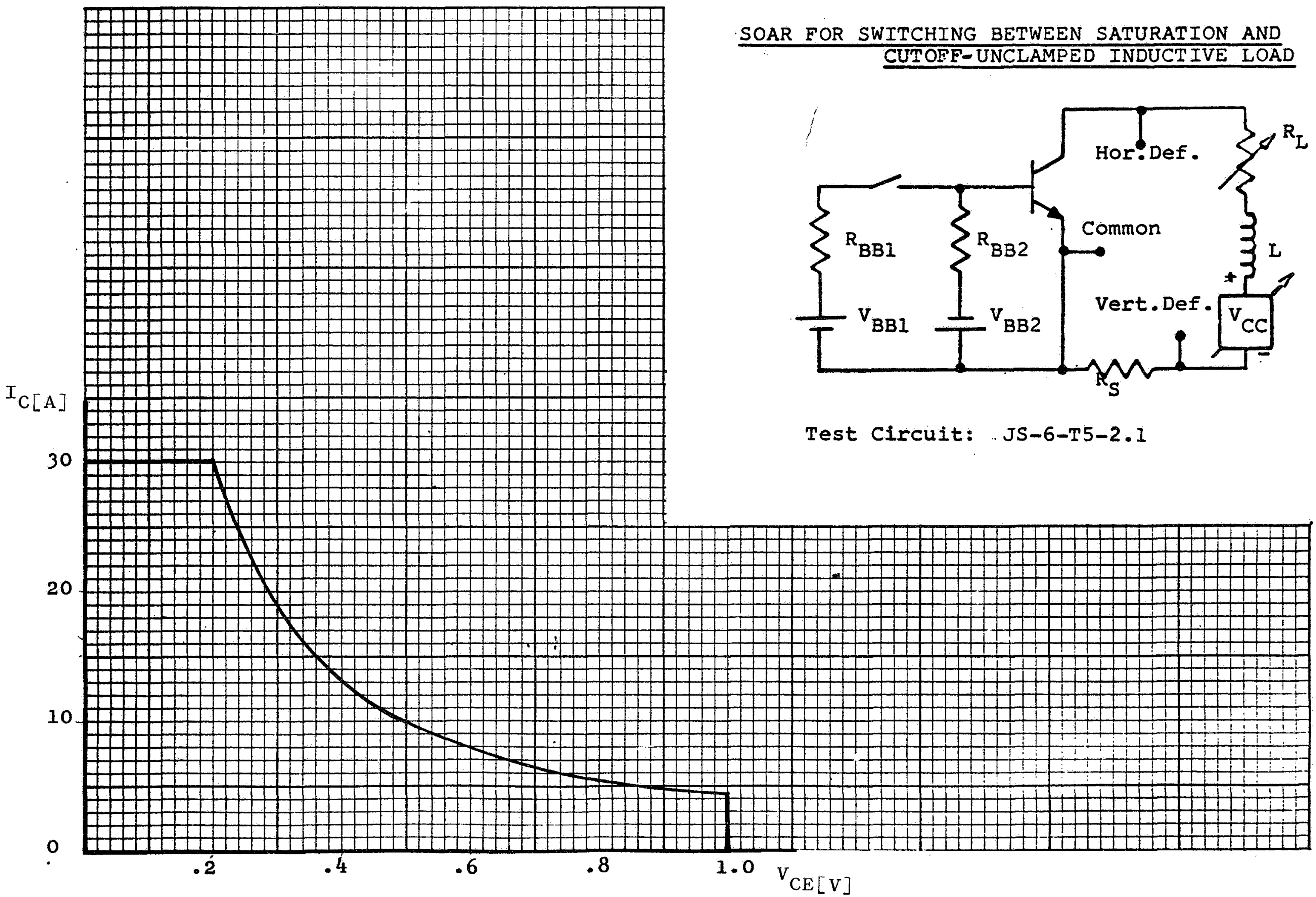

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD
Hor. Def.
Common
Vert. Def.
R_L
L
V_{CC}
R_{BB1}
R_{BB2}
V_{BB1}
V_{BB2}
R_S
Test Circuit: JS-6-T5-2.1
$I_{C[A]}$
30
20
10
0
.2
.4
.6
.8
1.0
$V_{CE[V]}$

Figure 5

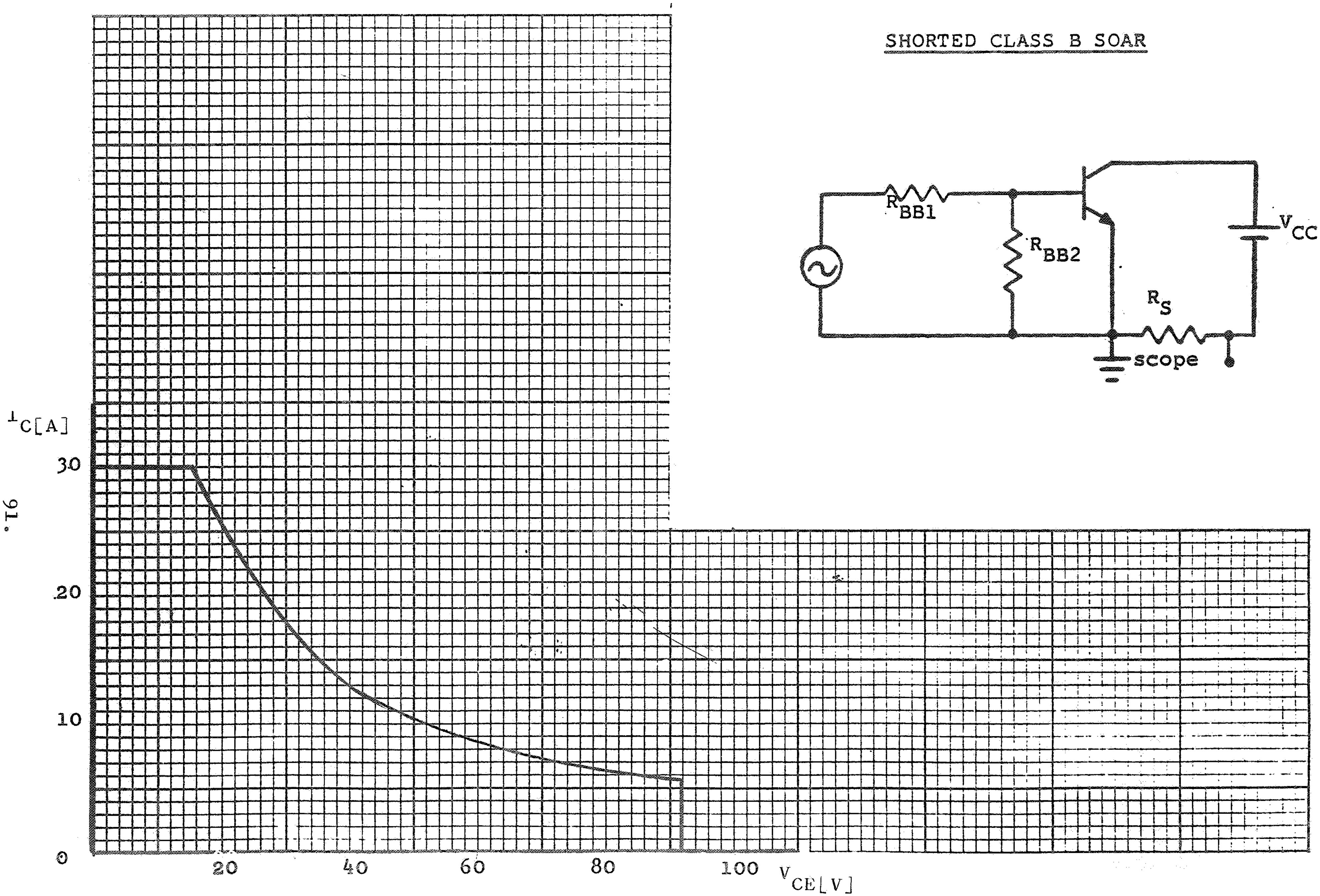

SHORTED CLASS B SOAR
R_{BB1}
R_{BB2}
V_{CC}
R_S
scope
I_C[A]
30
20
10
0
20
40
60
80
100
V_{CE}[V]

Figure 6

SILICON POWER TRANSISTOR

< Type 2N657A >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer E --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item		Test Method and Test Conditions
1.0.0	General Description	
1.1.0	Type - NPN	
1.2.0	Material - Silicon	
2.0.0	Mechanical Data	
2.1.0	Outline - TO-5	
2.2.0	Terminal Designation	
	1 - Emitter	
	2 - Base	
	3 - Collector	
	case - Collector	
3.0.0	Maximum Ratings	
3.1.0	Temperature	
3.1.1	$T_{STG(max)} = 200^{o}C$ $T_{STG(min)} = 200^{o}C$	JS-6-T1.2 [JEDEC publication No. 65 "Test Procedures for Verification of Maximum Ratings of Power Transistors"]
3.1.2	$T_{J(max)} = 200^{o}C$	JS-6-T2 $T_C = 100^{o}C$, $V_{CB} = 100V$, $I_C = 28.6mA$
3.1.3	$T(Lead) = 260^{o}C$	Distance from case = 1/16 in. Time = 10s
3.2.0	Voltage	$T_C = 25^{o}C$
3.2.1	$V_{CBO} = 100V$	JS-6-T3 or MIL-STD-750A, method 3001.1
3.2.2	$V_{EBO} = 8V$	JS-6-T4 of MIL-STD-750A, method 3026.1
3.2.3	$V_{CEX} = 100V$	JS-6-T5 $I_C(V_{CE} = V_{CEX}) = 0.5A$, $V_{CC} = 100V$, $R_L = 190\Omega$

Item		Test Methods and Test Conditions
3.2.3	V_{CEX} [cont'd]	L = 10mH; 0.11Ω (Stancor C-2688),
		CR = 1N1204, V_{BB1} = 10.1V, R_{BB1} = 33Ω
		V_{BB2} = 6.5V, R_{BB2} = 100Ω, t_p = 1ms,
		R_S = 1Ω, Duty Cycle = $\leq$ 1%
3.3.0	Current	
3.3.1	I_C = 500mA	JS-6-T6
		I_B = 50mA, T_C = 25°C
3.2.2	I_B = 250mA	JS-6-T8
		T_C = 25°C
3.3.3	I_E = 550mA	JS-6-T10
		I_B = 50mA, T_C = 25°C
3.4.0	Power	
3.4.1	P_T = 2.86W	JS-6-T13
		T_C = 100°C, V_{CC} = 100V, I_C = 0.5A
		V_{BB} = 6.5V, R_{BB} = 100Ω, Pulse Width 0.5ms
		Duty Cycle $\leq$ 1%, $t_r \leq$ 50µs, $t_f \leq$ 50µs
3.5.0	Maximum Operating Conditions	
3.5.1	Forward Biased Continuous DC-SOAR	JS-6-T12 [See Figure 1]
		T_C = 100°C
		Test Points: [See 3.1.2]

Item		Test Methods and Test Conditions
3.5.2	Pulsed Forward Biased SOAR	JS-6-T14 [See Figure 2] $T_C = 100^oC$, $I_C = 0.5A$, $R_S = 0.1\Omega$ $V_{BB} = 6.5V$, $R_{BB} = 100\Omega$, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$, Duty Cycle $\leq 1\%$ Test Points: 1. For $t_p \leq 5ms$, $V_{CC} = 35V$ 2. For $t_p \leq 2ms$, $V_{CC} = 50V$ 3. For $t_p \leq 1ms$, $V_{CC} = 65V$ 4. For $t_p \leq 0.5ms$, $V_{CC} = 100V$
3.6.0	SOAR Switching between Saturation and Cutoff	
3.6.1	Resistive Load	JS-6-T2.1 with L - 0 and CR disconnected [See Figure 3] $T_C = 100^oC$ Test Points: $t_r \leq 50\mu s$, $t_f \leq 50\mu s$, $I_C = 0.5A$, $V_{CC} = 100V$, $R_S = 0.1\Omega$, $R_{BB1} = 33\Omega$ $R_{BB2} = 100\Omega$, $V_{BB1} = 10.1V$, $V_{BB2} = 6.5V$
3.6.2	Clamped Inductive Load	JS-6-T5-2.1 [See Figure 4] $T_C = 25^oC$ Test Points: [See 3.2.3]
3.6.3	Unclamped Inductive Load	JS-6-T5-2.1 and CR disconnected [See Figure 5] $T_C = 25^oC$

Item		Test Methods and Test Conditions
3.6.3	Unclamped Inductive Load [cont'd]	$f = 1Hz$, Duty Cycle $\leq 5\%$, $R_S = 0.1\Omega$ $R_{BB1} = 33\Omega$, $R_{BB2} = 100\Omega$, $V_{BB1} = 10.1V$, $V_{BB2} = 6.5V$ 1. $L = 50mH$; 0.424Ω [series 2-Stancor C-2686], $I_C = 0.5A$, $V_{CC} = 9V$, $R_L = 9\Omega$ 2. $I_C = 0.15A$, $V_{CC} = 8V$, $R_L = 34\Omega$ $L = 600mH$; 6Ω [series 2-TRIAD C-47U]
3.7.0	Shorted Class B SOAR	[See Figure 6] Test Points: $I_{Cpeak} = 50mA$, $V_{CC} = 80V$, $R_S = 1\Omega$ $R_{BB1} = 10\Omega$, $R_{BB2} = 5\Omega$, $f \geq 20Hz$, $T_C = 100^oC$
4.0.0	Electrical Characteristics Maximum Limits unless otherwise noted Technique: DC - Continuous Operation C.T. - Curve Tracer P - 300µs Pulse, 2% Duty Cycle	$T_C = 25^oC$ [unless otherwise noted]

Item		Test Methods and Test Conditions
4.1.0	Static	
4.1.1	I_{CEO} = 100µA	V_{CEO} = 100V, Technique - C.T.
4.1.2	I_{CBO} = 10µA	V_{CBO} = 30V, Technique - C.T.
4.1.3	I_{CBO} = 250µA	V_{CBO} = 30V, T_C = 150°C Technique - C.T.
4.1.4	$V_{(BR)CEO}$ = 100V	I_C = 10mA, Technique - C.T.
4.1.5	V_{CBO} = 100V	I_C = 100µA, Technique - C.T.
4.1.6	V_{EBO} = 8V	I_E = 250µA, Technique - C.T.
4.1.7	h_{FE} = 30 min 90 max	V_{CE} = 10V, I_C = 200mA Technique = C.T.
4.1.8	h_{FE} = 20 min	V_{CE} = 10V, I_C = 0.5A, Technique - P
4.1.9	$V_{CE(sat)}$ = 2V	I_C = 200mA, I_B = 40mA, Technique - C.T.
4.1.10	$V_{CE(sat)}$ = 4V	I_C = 0.5A, I_B = 0.1A, Technique - C.T.
4.1.11	$V_{BE(sat)}$ = 3.5V	I_C = 0.5A, I_B = 0.1A, Technique - C.T.
4.1.12	h_{1E} = 200ohms	V_{CE} = 10V, I_B = 8mA, Technique - P
4.2.0	Dynamic	
4.2.1	f_{hfe} = 50KHz(min) 200KHz(max)	I_C = 50mA, V_{CE} = 10V
5.0.0	Thermal Characteristics	
5.1.0	$\tau_{J(min)}$ = 250ms	I_C = 0.2A, V_{CE} = 5V, T_C = 25°C, MIL-STD-750 Method 3146.1
5.2.0	$\theta_{J-C(max)}$ = 35 °C/W	I_C = 0.2A, V_{CE} = 5V, T_C = 25°C, MIL-STD-750 Method 3136

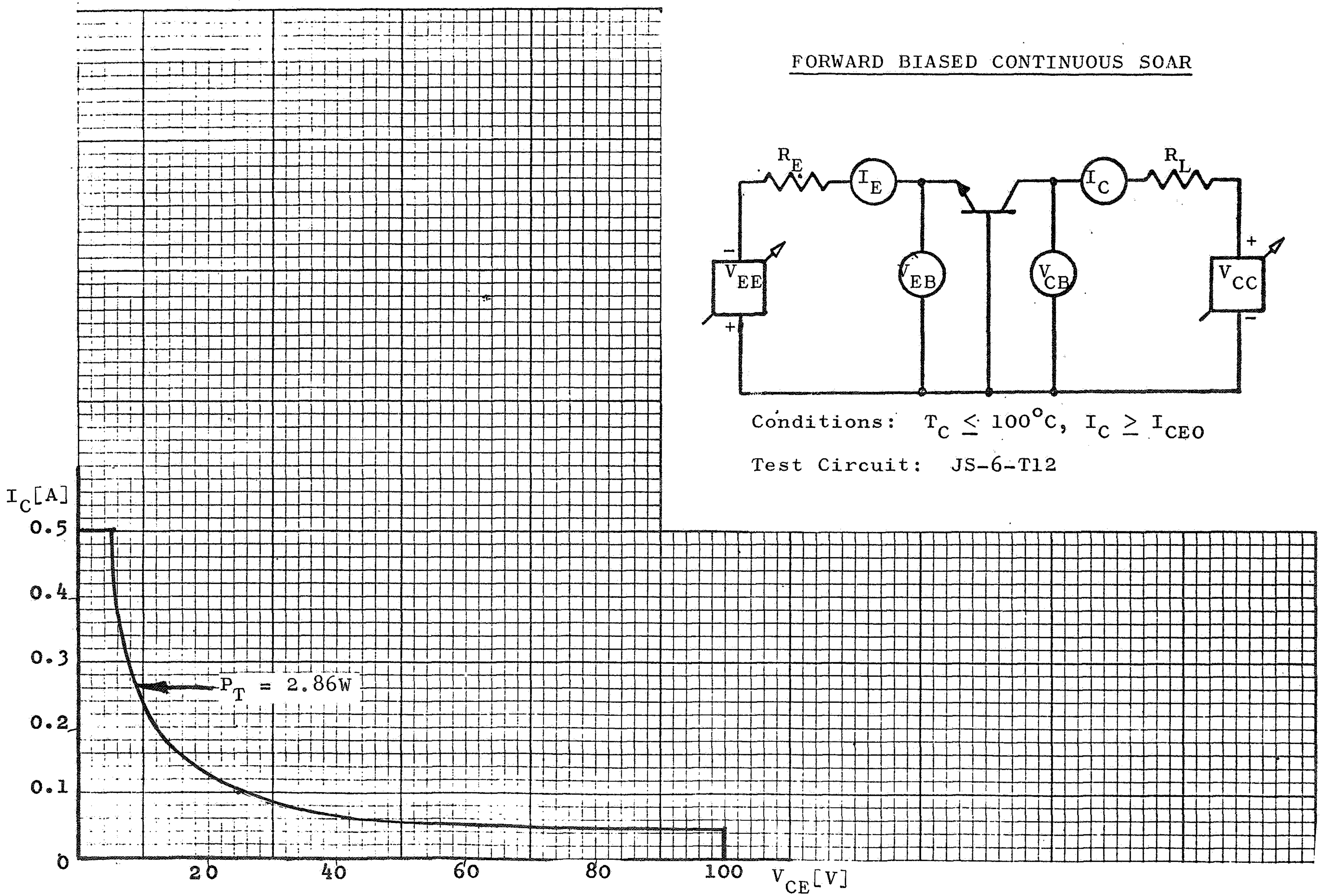
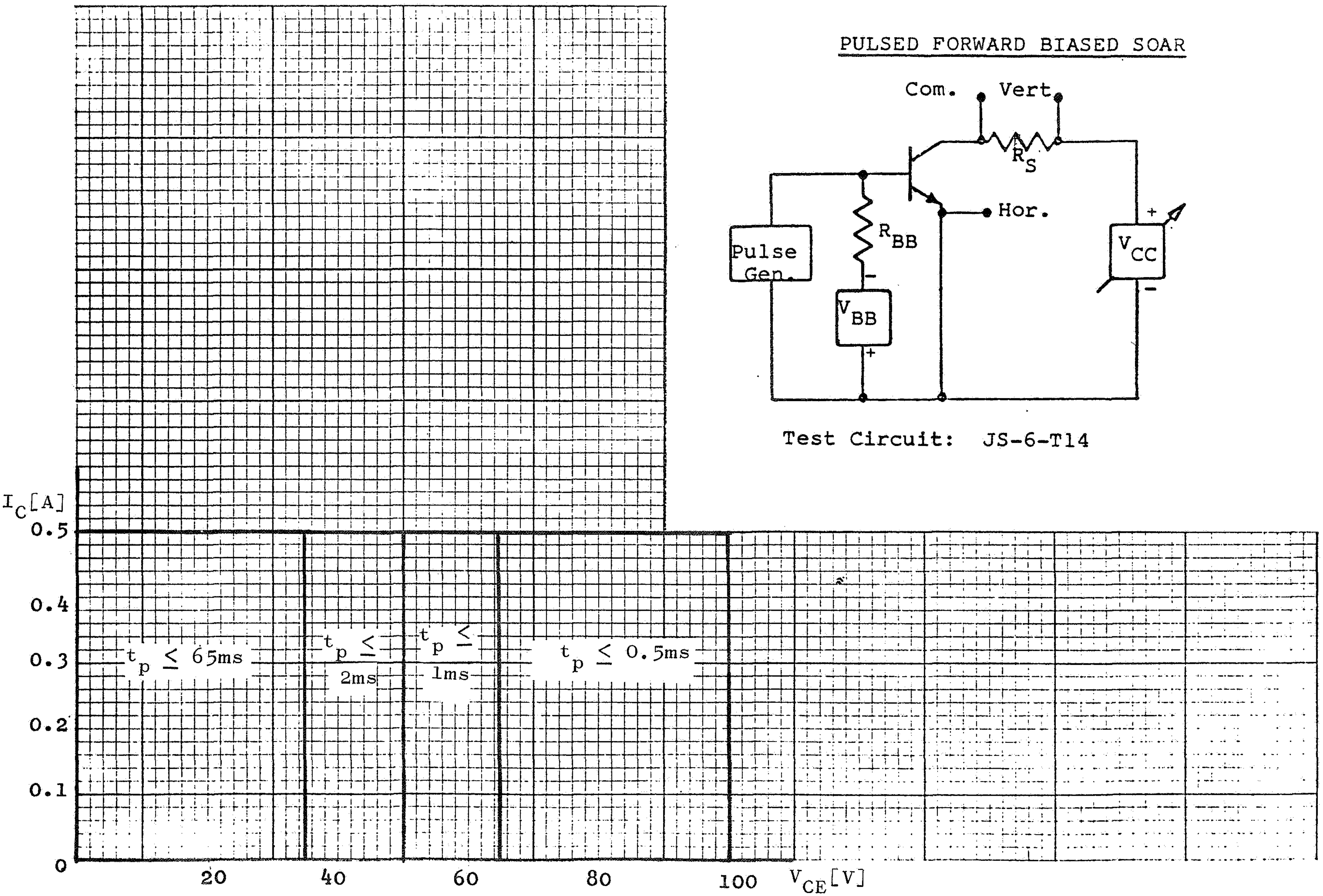

FORWARD BIASED CONTINUOUS SOAR
R_E
I_E
V_{EB}
V_{CB}
I_C
R_L
V_{EE}
V_{CC}
Conditions: $T_C \leq 100^\circ C$, $I_C \geq I_{CEO}$
Test Circuit: JS-6-T12
I_C[A]
0.5
0.4
0.3
0.2
0.1
0
20
40
60
80
100
V_{CE}[V]
P_T = 2.86W

Figure 1



PULSED FORWARD BIASED SOAR
Com.
Vert.
R S
Hor.
Pulse Gen.
R BB
V BB
V CC
Test Circuit: JS-6-T14
I C [A]
0.5
0.4
0.3
0.2
0.1
0
20
40
60
80
100
V CE [V]
t p ≤ 65ms
t p ≤ 2ms
t p ≤ 1ms
t p ≤ 0.5ms

Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

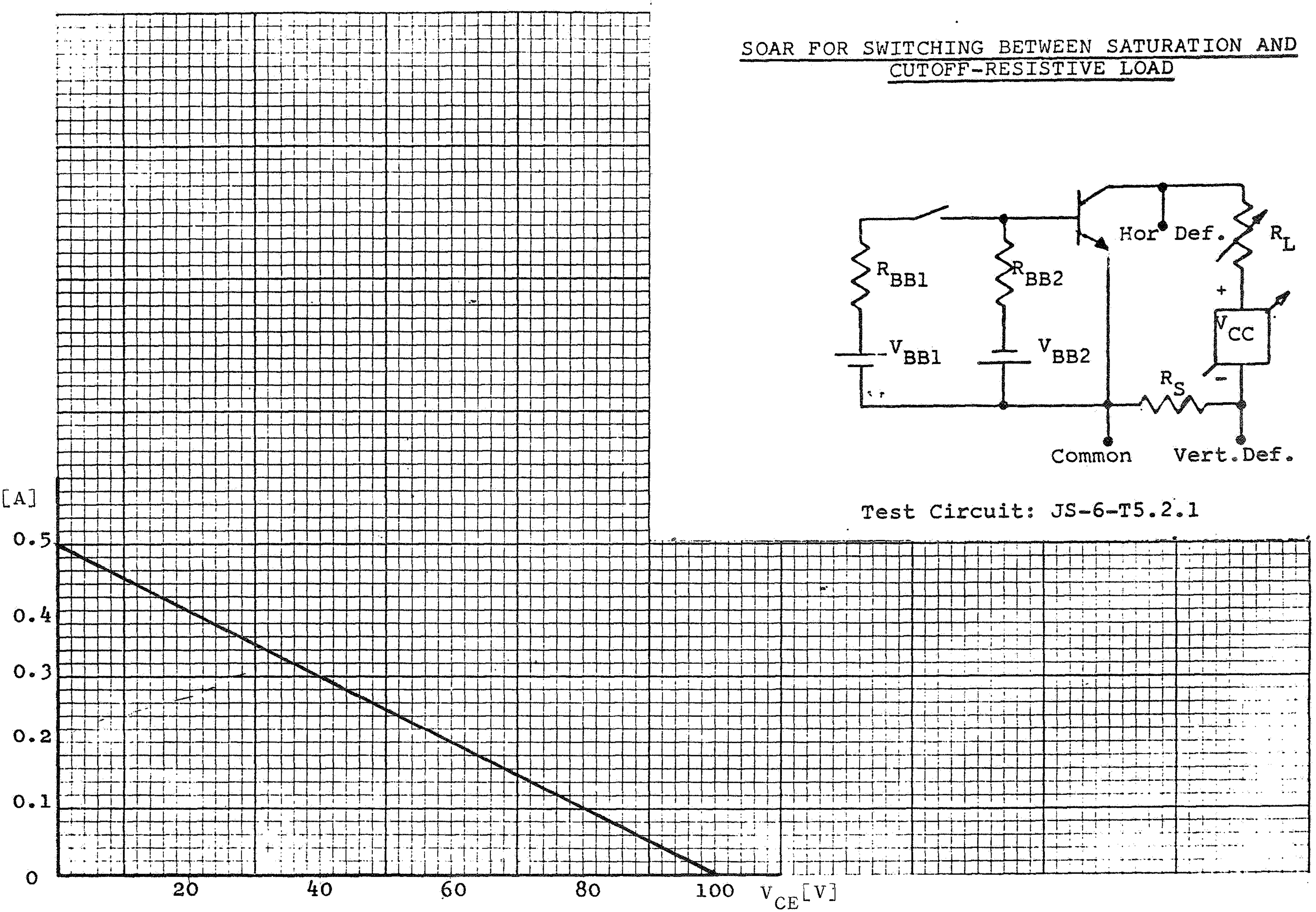
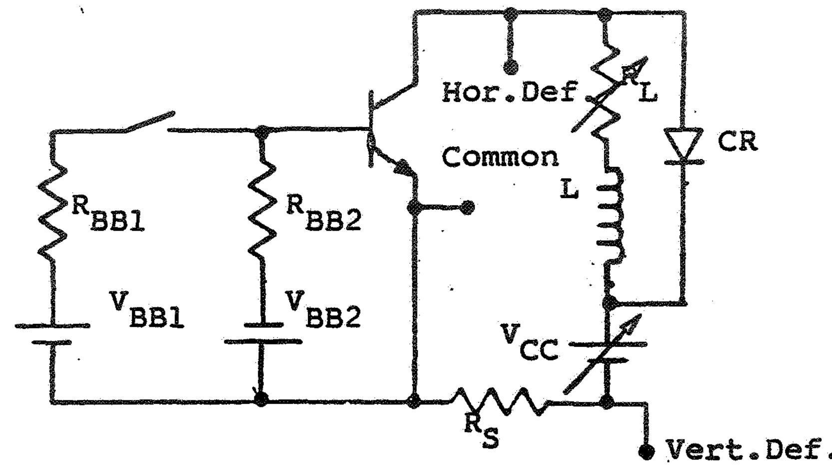
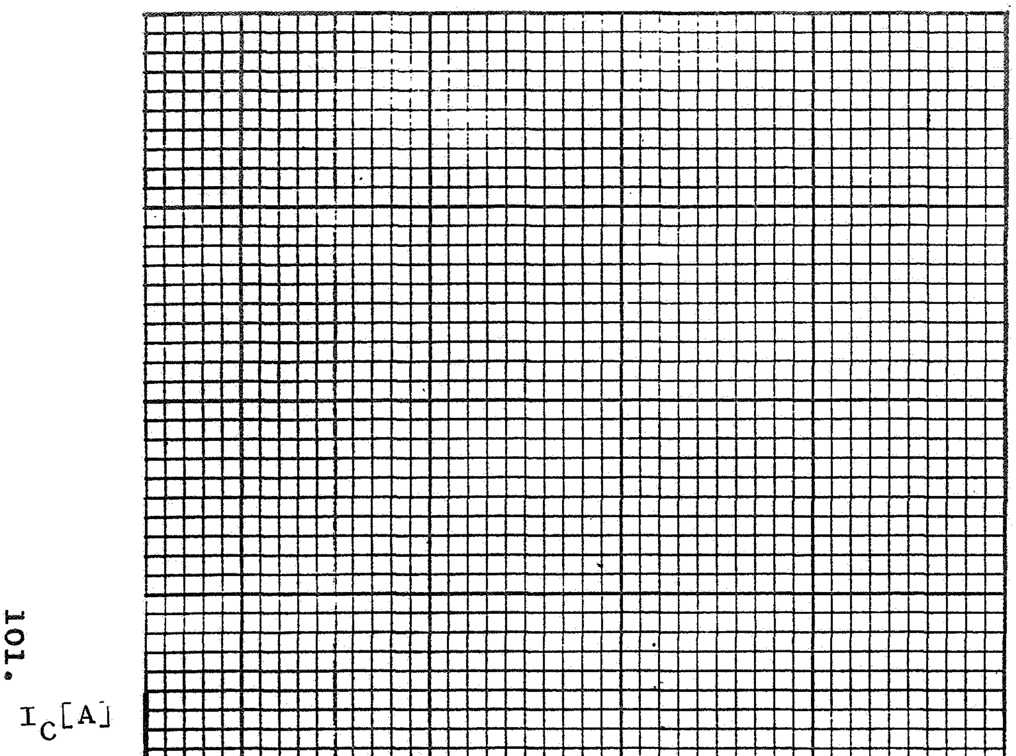


Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1



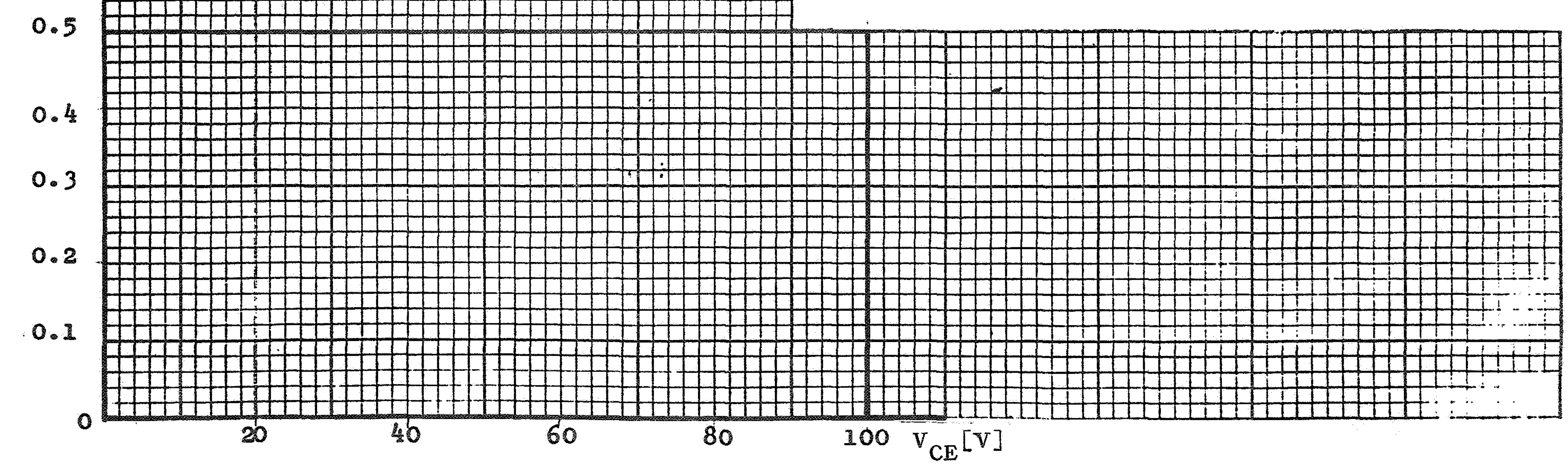


Figure 4

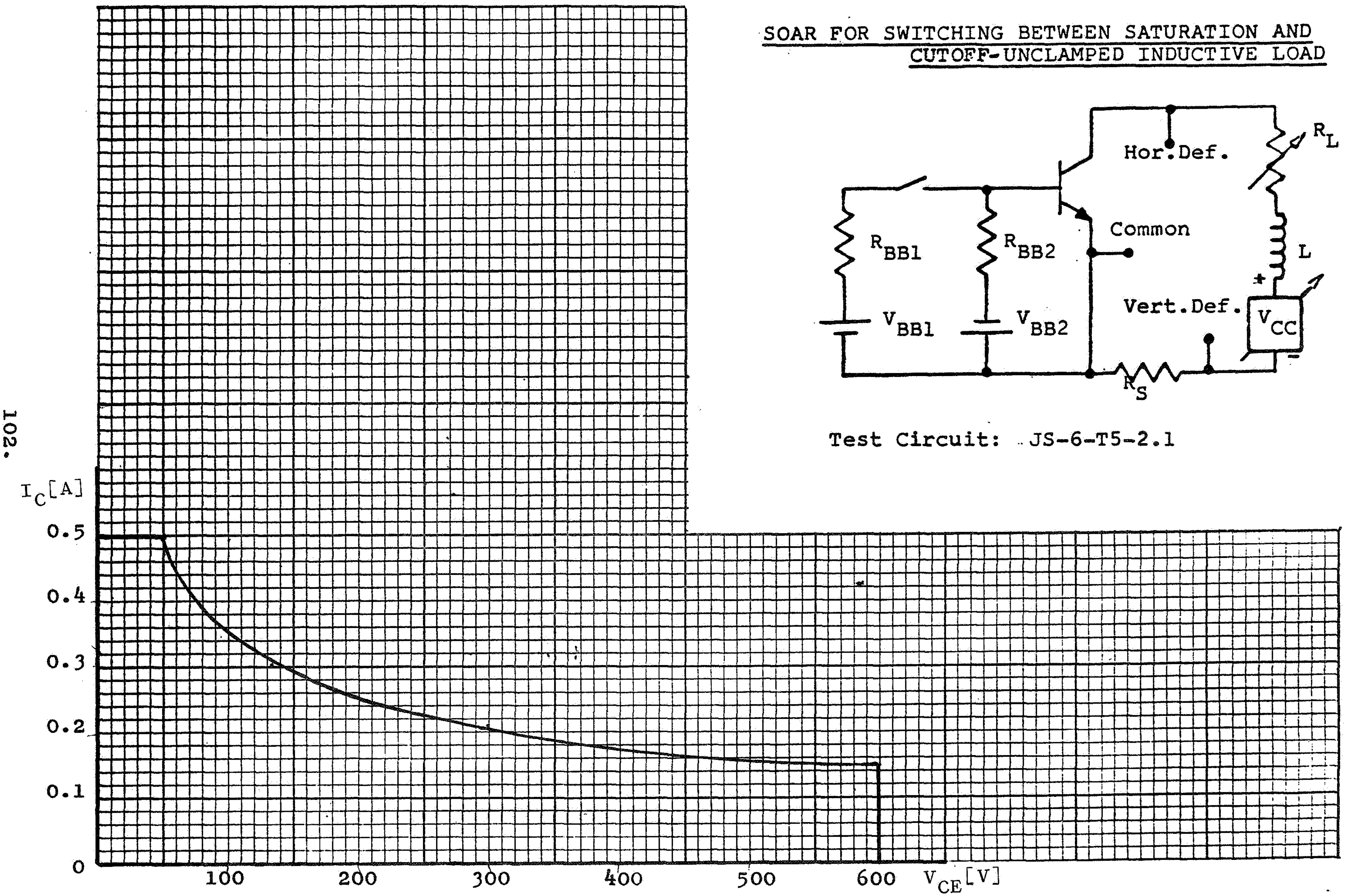

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD
R_L
L
V_{CC}
Hor. Def.
Common
Vert. Def.
R_S
R_{BB1}
V_{BB1}
R_{BB2}
V_{BB2}
Test Circuit: JS-6-T5-2.1
I_C[A]
0.5
0.4
0.3
0.2
0.1
0
100
200
300
400
500
600
V_{CE}[V]

Figure 5

SHORTED CLASS B SOAR

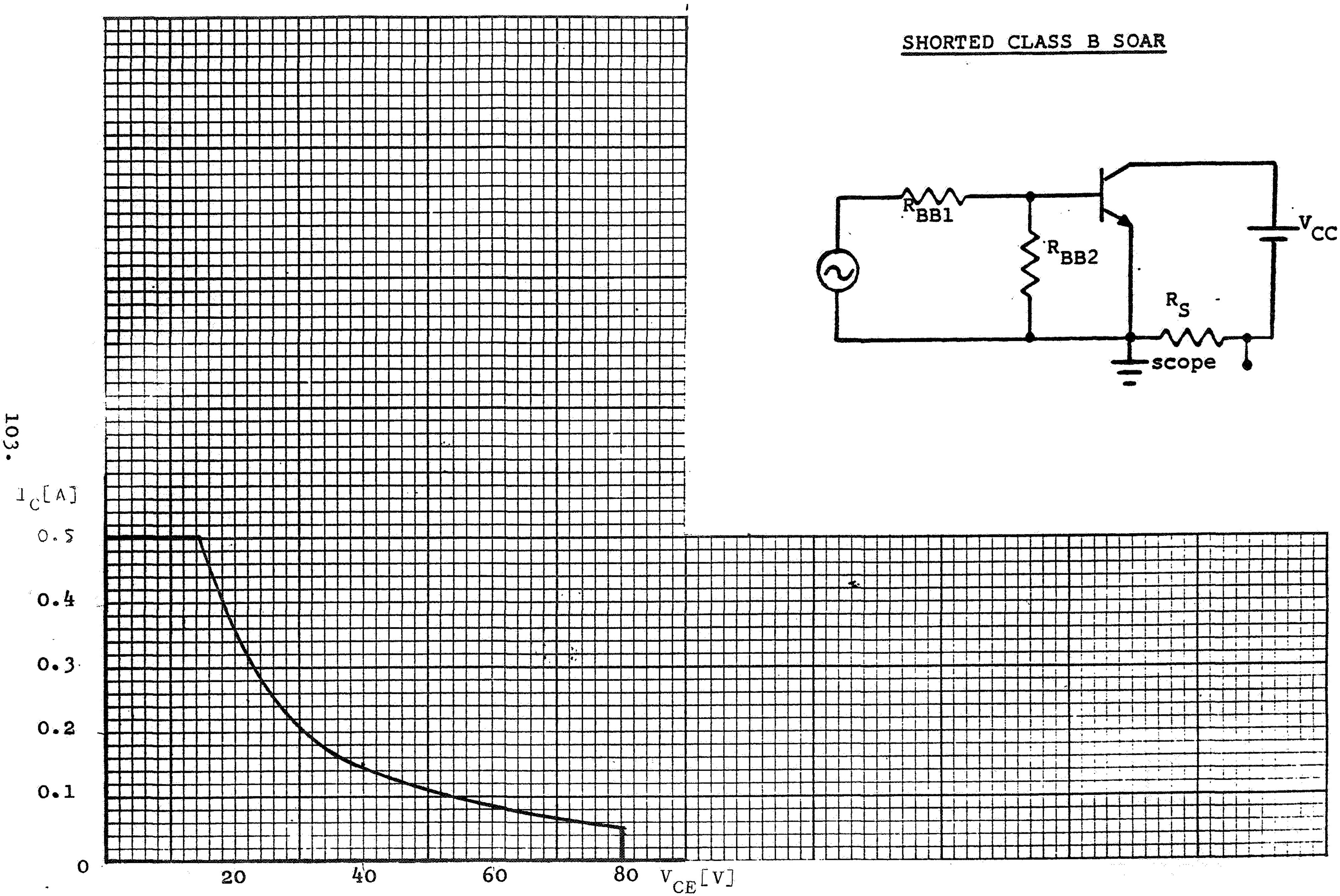


Figure 6

SILICON POWER TRANSISTOR

< Type 2N697 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufactuers E & G --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item		Test Methods and Test Conditions
1.0.0	General Description	
1.1.0	Type - NPN	
1.2.0	Material - Silicon	
2.0.0	Mechanical Data	
2.1.0	Outline - TO-5	
2.2.0	Terminal Designation 1 -- Emitter 2 -- Base 3 -- Collector case -- Collector	
3.0.0	Maximum Ratings	
3.1.0	Temperature	
3.1.1	$T_{STG(min)} = -65^{o}C$ $T_{STG(max)} = 300^{o}C$	JS-6-T1.1 JS-6-T1.2 [JEDEC Publication No. 65 "Test Procedures for Verification of Maximum Ratings of Power Transistors"]
3.1.2	$T_J = 175^{o}C$	JS-6-T2 $T_C = 100^{o}C$, $V_{CB} = 40V$, I_C 0.025A
3.1.3	$T(Lead) = 260^{o}C$	Distance from case = 1/16 in Time 10s
3.2.0	Voltage	$T_C = 25^{o}C$
3.2.1	$V_{CBO} = 60V$	JS-6-T3 or MIL-STD-750A, Method 3001.1
3.2.2	$V_{EBO} = 5V$	JS-6-T4 or MIL-STD-750A, Method 3026.1
3.2.3	$V_{CEX} = 40V$	JS-6-T5 $I_{C(V_{CC} = V_{CEX})} = 0.5A$, $V_{CC} = 40V$, $R_L = 72\Omega$

Item		Test Methods and Test Conditions
3.2.3	V_{CEX} [cont'd]	L = 10mH / 0.11Ω, [Stancor C-2699]
		CR = 1N1204, V_{BB1} = 8.5V, R_{BB1} = 30Ω
		V_{BB2} = 4V, R_{BB2} = 65Ω, Duty Cycle =
		$\leq$ 1%
3.3.0	Current	
3.3.1	I_C = 0.5A	JS-6-T6
		I_B = 0.05A, T_C = 25°C
3.3.2	I_B = 0.1A	JS-6-T8
		T_C = 25°C
3.3.3	I_E = 0.55A	JS-6-T10
		I_B = 0.05A, T_C = 25°C
3.4.0	Power	
3.4.1	P_T = 1W	JS-6-T12
		T_C = 100°C , V_{CB} = 40V, I_C = 0.025A
		Derating Factor = 13.3mW/°C
3.4.2	P_{TM} = 20W	JS-6-T13
		T_C = 100°C, V_{CC} = 40V, I_C = 0.5A,
		V_{BB} = 4V, R_{BB} = 65Ω, Pulse Width = 0.1m
		Duty Cycle $\leq$ 1%, $t_r \leq$ 50μs,
		$t_f \leq$ 50μs
3.5.0	Maximum Operating Conditions	
3.5.1	Forward Biased Continuous DC SOAR	JS-6-T12 [See Figure 1]

Item		Test Methods and Test Conditions
3.5.1	Forward Biased Continuous DC SOAR [cont'd]	$T_C = 100^oC$ Test Point: [See 3.4.1]
3.5.2	Pulsed Forward Biased SOAR	JS-6-T14 [See Figure 2] Test Point: $T_C = 100^oC$, $I_C = 0.5A$, $R_S = 1\Omega$ $V_{BB} = 4V$, $R_{BB} = 65\Omega$, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$, Duty Cycle $\leq 1\%$ 1. For $t_p = 10ms$; $V_{CC} = 10V$ 2. For $t_p = 1ms$; $V_{CC} = 18V$ 3. For $t_p = 0.5ms$; $V_{CC} = 30V$ 4. For $t_p = 0.1ms$; $V_{CC} = 40V$
3.6.0	SOAR Switching between Saturation and Cutoff	
3.6.1	Resistive Load	JS-6-T5-2.1 with L - 0 and CR disconnected [See Figure 3] $T_C = 100^oC$ Test Point: $V_{CC} = 60V$, $I_C = 0.5A$, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$, $R_{BB1} = 30\Omega$, $R_{BB2} = 65\Omega$, $V_{BB1} = 8.5V$, $V_{BB2} = 4V$
3.6.2	Clamped Inductive Load	JS-6-T5-2.1 [See Figure 4] $T_C = 25^oC$ Test Point: [See 3.2.3]

Item		Test Methods and Test Conditions
3.6.3	Unclamped Inductive Load	JS-6-T5-2.1 and CR disconnected [See Figure 5] $T_C = 25^oC$ Test Point: f = 60Hz, Duty Cycle $\leq$ 1% $R_S = 1\Omega$, $t_r \leq 50\mu s$, $t_f \leq 50\mu s$ 1. $R_{BB1} = 30\Omega$, $R_{BB2} = 65\Omega$, $V_{BB1} = 8.5V$, $V_{BB2} = 4V$, L = 10mH / 0.11Ω, (Stancor C-2688) 2. $R_{BB1} = 120\Omega$, $R_{BB2} = 150\Omega$, $V_{BB1} = 5V$, $V_{BB2} = 2V$, $I_C = 0.1A$, $V_{CC} = 14V$, $R_L = 125\Omega$, L = 100mH / 1.175Ω, (Series Stancor C-2688 and TRIAD C-47u)
3.7.0	Shorted Class B SOAR	[See Figure 6] Test Points: $I_{C\ peak} = 0.05A$, $V_{CC} = 40V$, $R_S = 10\Omega$, $R_{BB1} = 10\Omega$; $R_{BB2} = 27\Omega$; f = 20Hz, $T_C = 100^oC$
4.0.0	Electrical Characteristics Maximum Limits unless otherwise noted	$T_C = 25^oC$ [unless otherwise noted]

Item		Test Methods and Test Conditions
4.0.0	Electrical Characteristics [Cont'd]	
	Technique:	
	DC – Continuous Operation	
	C.T. – Curve Tracer	
	P – 300μs Pulse, 2% Duty Cycle	
4.1.0	Static	
4.1.1	I_{CEO} = 10μA	V_{CEO} = 40V Technique – C.T.
4.1.2	I_{CBO} = 1μA	V_{CBO} = 30V Technique – C.T.
4.1.3	I_{CBO} = 100μA	V_{CBO} = 30V, T_C = 150°C, Technique-C.T.
4.1.4	V_{CBO} = 60V	I_C = 100μA Technique – C.T.
4.1.5	V_{CER} = 40 V	I_C = 100μA, $R_B \leq 10\Omega$ Technique-C.T.
4.1.6	V_{EBO} = 5V	I_E = 100μA Technique – C.T.
4.1.7	$V_{(BR)CEO}$ = 30V min	I_C = 0.05A Technique – C.T.
4.1.8	h_{FE} = 40 min 120 max	V_{CE} = 10V, I_C = 0.15A Technique – P
4.1.9	h_{FE} = 25 min	V_{CE} = 10V, I_C = 0.5A Technique – P
4.1.10	$V_{CE(sat)}$ = 1.5V	I_C = 0.15A, I_B = 0.015A, Technique – C.T.
4.1.11	$V_{CE(sat)}$ = 4V	I_C = 0.5A, I_B = 0.1A Technique – P
4.1.12	$V_{BE(sat)}$ = 1.3V	I_C = 0.15A, I_B = 0.015A Technique – C.T.
4.1.13	$V_{BE(sat)}$ = 2.5V	I_C = 0.5A, I_B = 0.1A Technique – P
4.2.0	Dynamic	

Item		Test Methods and Test Conditions
4.2.1	f_T = 50MHz min 160MHz max	I_C = 0.05A, V_{CE} = 10V f = 20MHz
4.2.2	C_{obo} = 35pF	V_{CB} = 10V, f = 1MHz
5.0.0	Thermal Characteristics	
5.1.0	${}_{J(min)}$ = 70ms	I_C = 0.4A, V_{CE} = 5V, MIL-STD-750 Method 3146.1
5.2.0	$\theta_{J-C(max)}$ = $75^{o}C/W$	I_C = 0.4A, V_{CE} = 5V, T_C = $20^{o}C$ MIL-STD-750 Method 3136
5.3.0	$\theta_{J-A(max)}$ = $250^{o}C/W$	

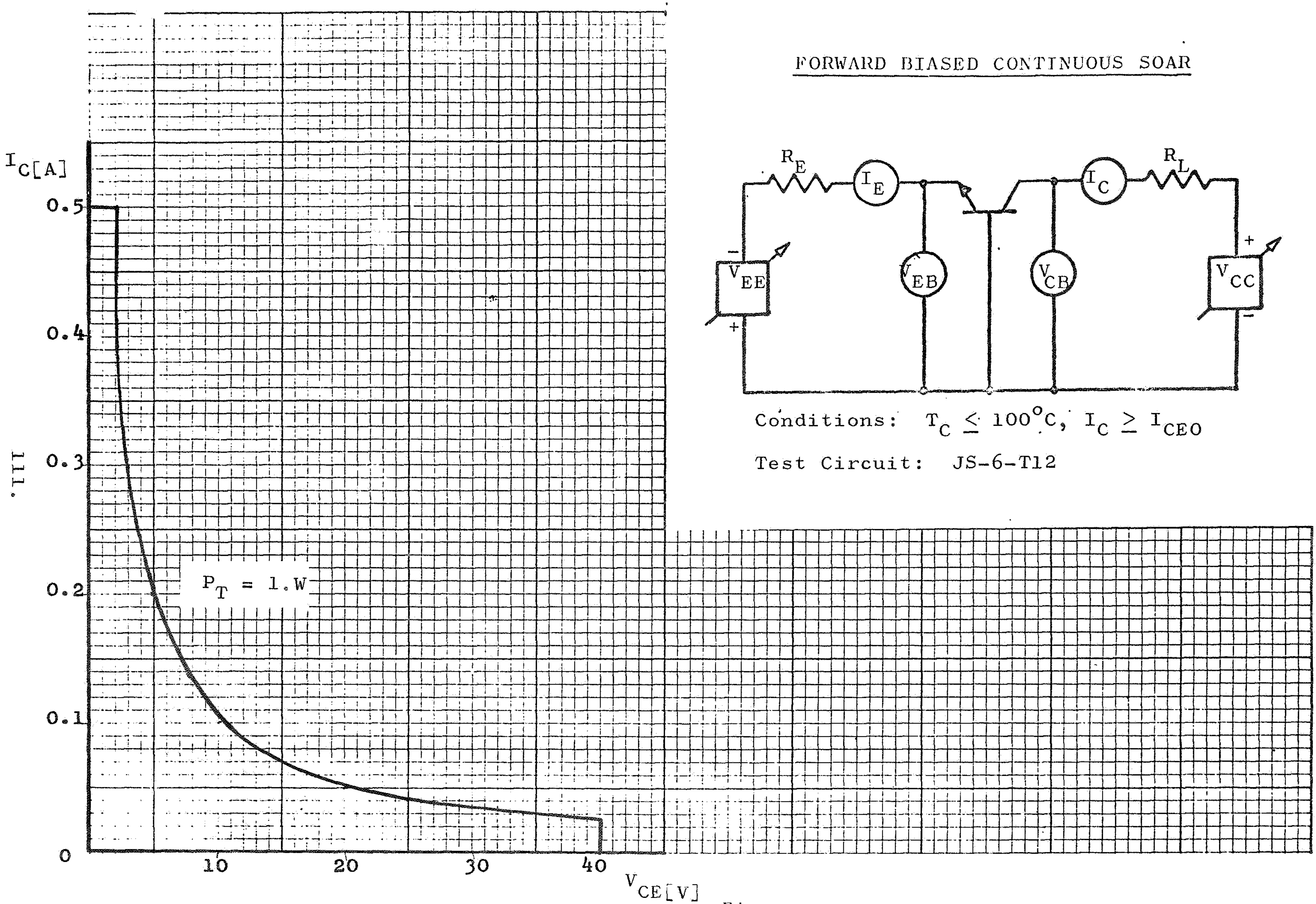
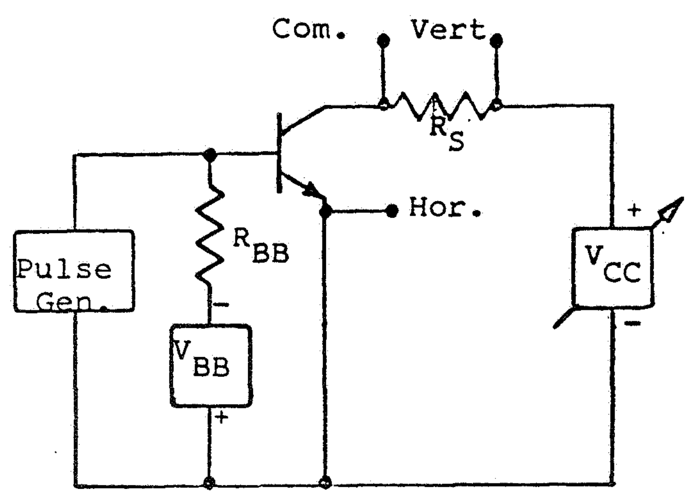

FORWARD BIASED CONTINUOUS SOAR
R_E
I_E
V_EE
V_EB
V_CB
I_C
R_L
V_CC
Conditions: $T_C \leq 100^oC$, $I_C \geq I_{CEO}$
Test Circuit: JS-6-T12
I_C[A]
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
V_CE[V]
P_T = 1.W

Figure 1

PULSED FORWARD BIASED SOAR



Test Circuit: JS-6-T14

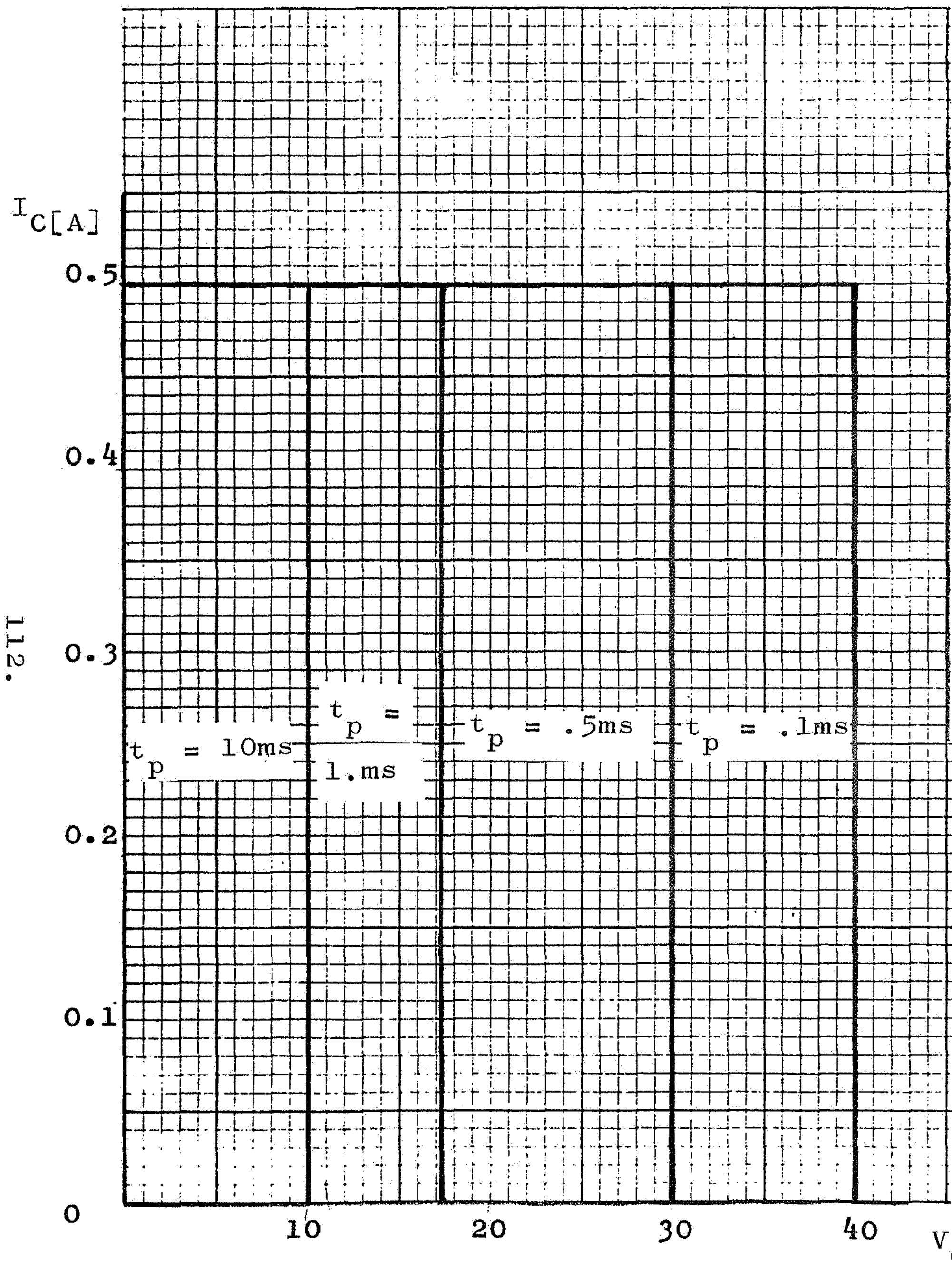
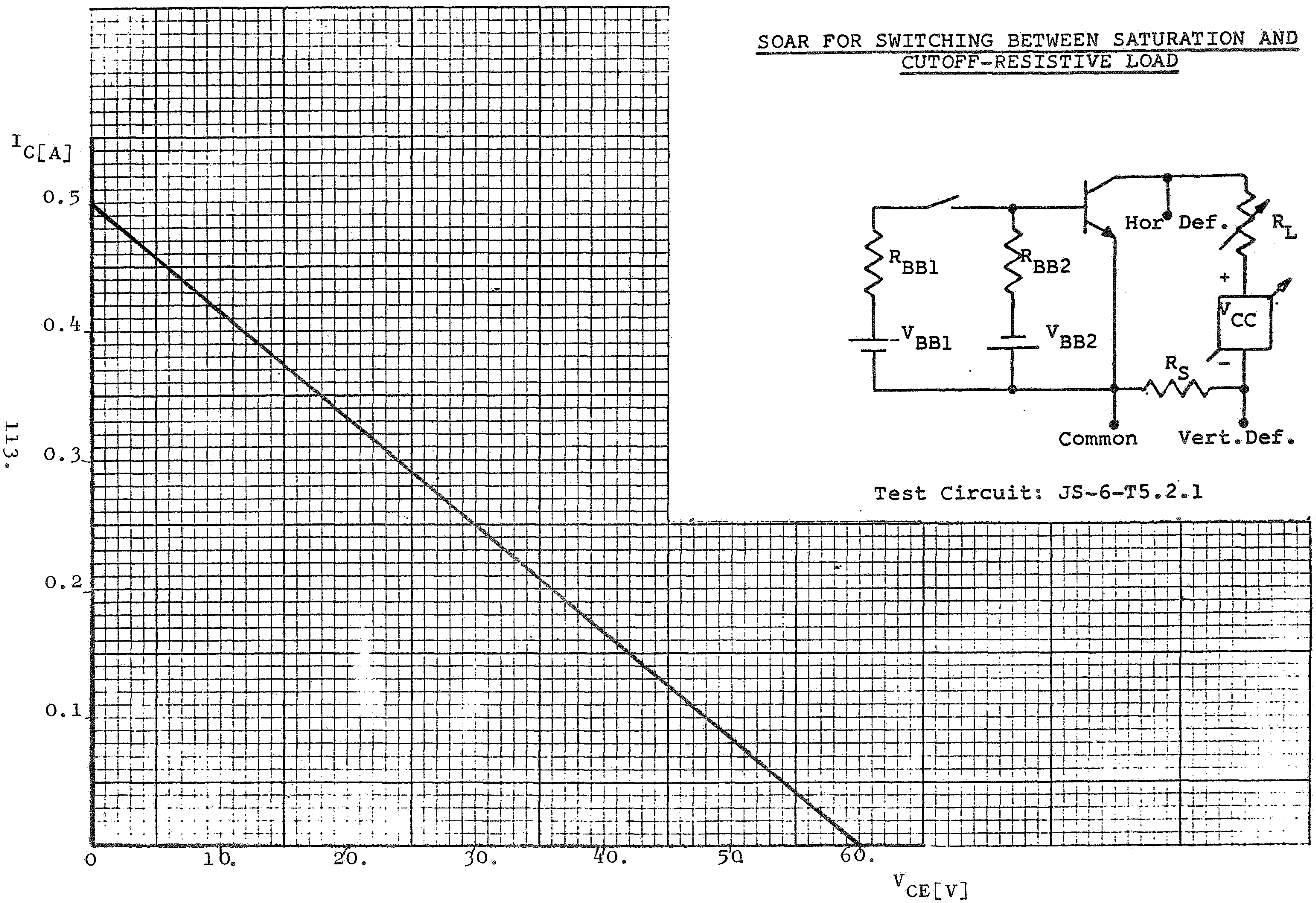


Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD



Test Circuit: JS-6-T5.2.1

Figure 3

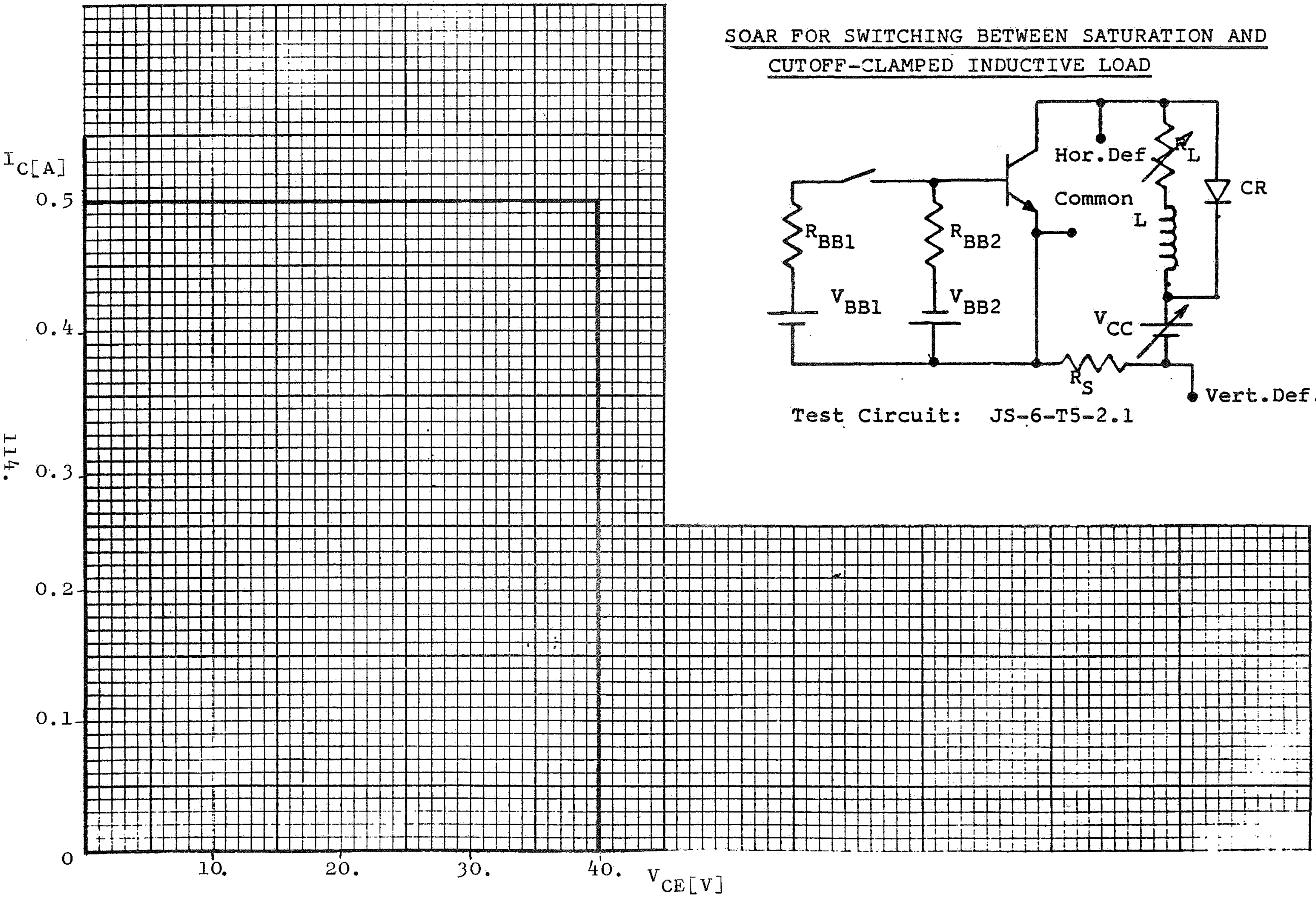

SOAR FOR SWITCHING BETWEEN SATURATION AND
CUTOFF-CLAMPED INDUCTIVE LOAD
Hor.Def
R_L
CR
Common
L
R_{BB1}
R_{BB2}
V_{BB1}
V_{BB2}
V_{CC}
R_S
Vert.Def.
Test Circuit: JS-6-T5-2.1
I_C[A]
0.5
0.4
0.3
0.2
0.1
0
10.
20.
30.
40.
V_{CE}[V]

Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD

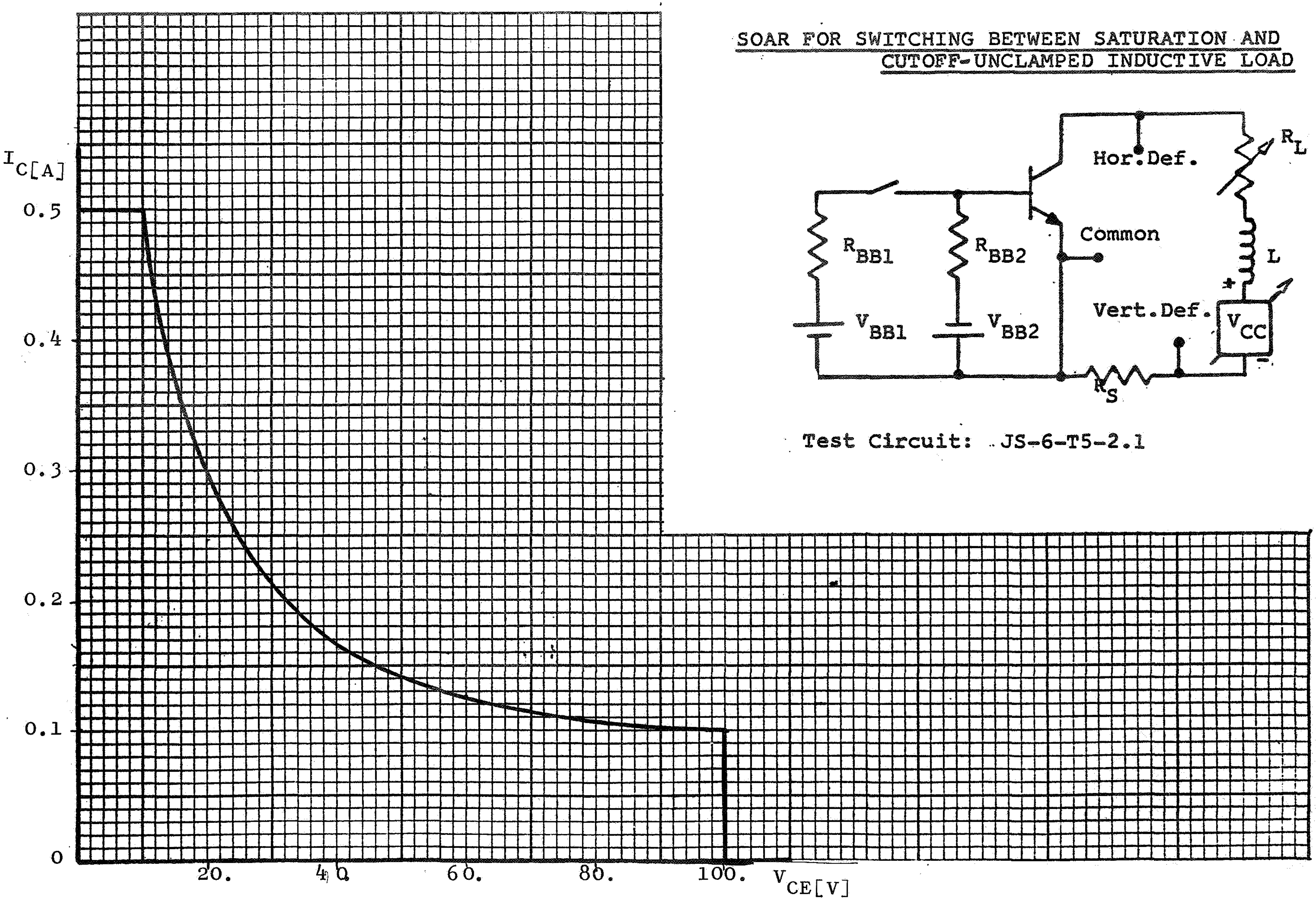


Figure 5

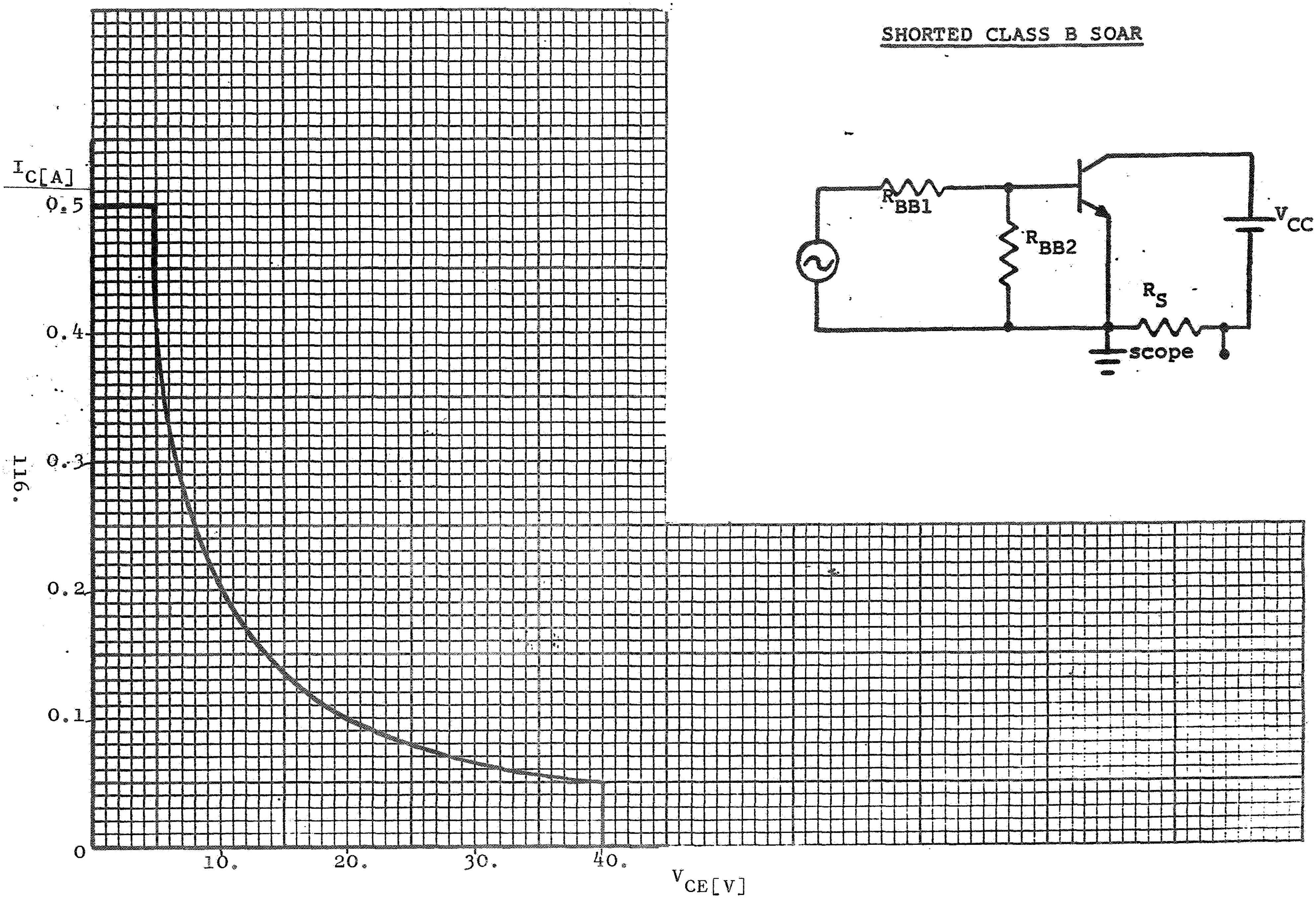

SHORTED CLASS B SOAR
R_{BB1}
R_{BB2}
V_{CC}
R_S
scope
I_C[A]
0.5
0.4
0.3
0.2
0.1
0
10.
20.
30.
40.
V_{CE}[V]

Figure 6

-- TEST REPORT --

SILICON POWER TRANSISTOR

< 2N2880 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer H --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item		Test Methods and Test Conditions
1.0.0	General Description	
1.1.0	Type = NPN	
1.2.0	Material = Silicon	
2.0.0	Mechanical Data	
2.1.0	Outline = TO-111	
2.2.0	Terminal Designation	
	1. --- Emitter	
	2. --- Base	
	3. --- Collector	
	Case - Collector	
3.0.0	Maximum Ratings	
3.1.0	Temperature	
3.1.1	$T_{STG(min)} = -65^oC$	JS-6-T1.1
	$T_{STG(max)} = +200^oC$	JS-6-T1.2
3.1.2	$T_{J(max)} = 200^oC$	JS-6-T2
		$T_C = 100^oC$
		$P_T = 30W$, $I_C = 5A$
3.1.3	T (Lead) = $+230^oC$	Distance from case = 1/16"
		Time = 10 sec.
3.2.0	Voltage	$T_C = 25^oC$
3.2.1	$V_{CBO} = 100V$	JS-6-T3 or MIL-STD-750A
		Method 3001.1

Item		Test Methods and Test Conditions
3.2.2	$V_{EBO} = 8V$	JS-6-T3 or MIL-STD-750A Method 3026.1
3.2.3	$V_{CEX} = 100V$	JS-6-T4 or MIL-STD-750A Method 3053 $I_C \ (V_{CE} = V_{CEX}) = 5A$ $V_{CC} = 100V, \ R_L = 19.5\Omega$ $L^* = 1.0mH, \ CR = 1N1204$ $V_{BB1} = 9V, \ R_{BB1} = 5\Omega$ $V_{BB2} = 2.5V, \ R_{BB2} = 5\Omega$ Pulse width = 1.0ms, Duty Cycle = 2% $R_S = 0.1\Omega, \ t_r \leq 50\mu s$ $t_f \leq 50\mu s$ *Miller No. 7871 in series with Miller No. 7825-3
3.3.0	Current	
3.3.1	$I_C = 5A$	JS-6-T6 $I_B = 0.5A, \ T_C \leq 25^oC$
3.3.2	$I_B = 0.5A$	JS-6-T8 $T_C \leq 25^oC$
3.4.0	Power	
3.4.1	$P_T = 30W$	TS-6-T12 or MIL-STD-750A Method 3051 $T_C \leq 100^oC$
	Derating Factor= 0.3 $W/^oC$	$V_{CB} \approx 30V, \ I_C = 1A$

Item	Test Methods and Test Conditions
3.4.2 $P_{TM} = I_C V_{CC} = 350W$	JS-6-T13 or MIL-STD-750A Method 3052 $T_C = 100^oC$, $V_{CC} = 70V$ $V_{BB} = 2.5V$, $R_{BB} = 5\Omega$ Pulse width = 0.5ms Duty Cycle $\leq$ 1% $t_r \leq 50\mu s$, $t_f \leq 50\mu s$
3.5.0 Maximum Operating Conditions	
3.5.1 Forward Biased Continuous DC SOAR	JS-6-T12 or MIL-STD-750A Method 3051 [see figure 1] Test Points: 1. [see 3.4.1] 2. $V_{CB} \approx 70V$, $I_C = 0.2A$, $T_C = 100^oC$, $P_T = 14W$
3.5.2 Pulsed Forward Biased SOAR	JS-6-T1.4 or MIL-STD-750A Method 3052 Test Points: [see figure 2] $T_C \leq 100^oC$, $V_{BB} = 2.5V$ $R_{BB} = 5\Omega$, $I_C = 5A$ $t_r \leq 50\mu s$, $t_f \leq 50\mu s$ Duty Cycle $\leq$ 1%, $R_S = 0.1\Omega$ 1. For $t_p = 5ms$; $V_{CC} = 20V$ 2. For $t_p = 2.5ms$; $V_{CC} = 35V$ 3. For $t_p = 1ms$; $V_{CC} = 50V$ 4. For $t_p = 0.5ms$; $V_{CC} = 70V$

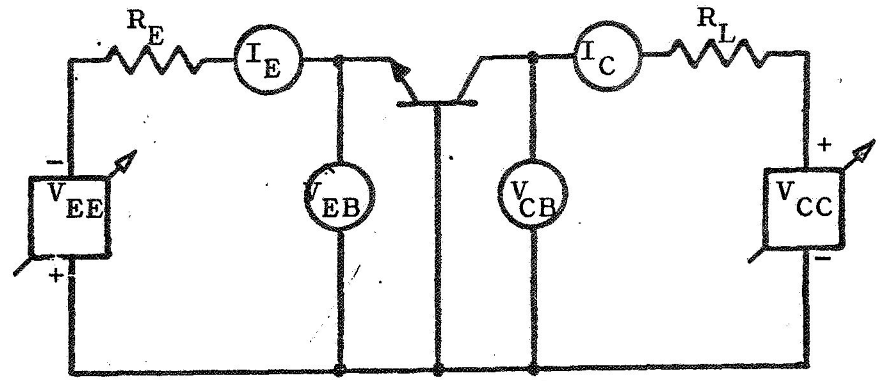
Item	Test Methods and Test Conditions
3.6.0 SOAR Switching between Saturation and Cutoff	
3.6.1 Resistive Load	JS-6-T5.1 or MIL-STD-750A Method 3053 with L = 0 and CR disconnected [see figure 3] Test Points: I_C = 5A, V_{CC} = 100V, R_{BB1} = 5Ω R_{BB2} = 5Ω, V_{BB1} = 9V, V_{BB2} = 2.5V T_C = 100°C; R_S = 0.1Ω $t_r \leq 50\mu s$, $t_f \leq 50\mu s$ Collector Current
3.6.2 Clamped Inductive Load	JS-6-T5.1 or MIL-STD-750A Method 3053 [see figure 4] Test Points: I_C = 5A, V_{CC} = 100V, R_L = 19.5Ω L = 1mH, R_{BB1} = 5Ω, R_{BB2} = 5Ω V_{BB1} = 9V, V_{BB2} = 2.5V, t_p = 1ms, CR = 1N1204, T_C = 25°C, $t_r \leq 50\mu s$ $t_f \leq 50\mu s$, Duty Cycle = 2% R_S = 0.1Ω
3.6.3 Unclamped Inductive Load	JS-6-T5.1 or MIL-STD-750A Method 3053 with CR disconnected Test Points: [see figure 5] R_{BB1} = 5Ω, R_{BB2} = 5Ω, R_S = 0.1Ω V_{BB1} = 9V, V_{BB2} = 2.5V, f = 20Hz

Item		Test Methods and Test Conditions
3.6.3	[Cont'd]	$T_C = 25^oC$ 1. $I_C = 4A$, $V_{CC} = 30V$, $R_L = 7\Omega$ $L = 125\mu H$ - Two Miller 7825-3 in parallel 2. $I_C = 0.5A$, $V_{CC} = 10V$, $R_L = 19\Omega$ $L = 10mH$ - Stancor C-2688
3.7.0	Shorted Class B SOAR	[see figure 6] Test Points: I_C (peak) $= 0.3A$, $V_{CC} = 70V$, $R_S = 0.1\Omega$, $R_{BB1} = 1\Omega$, $R_{BB2} = 3\Omega$, $f = 20Hz$, $T_C = 100^oC$
4.0.0	Electrical Characteristics	
	Maximum limits unless otherwise noted.	$T_C = 25^oC$ [unless otherwise noted]
	Techniques: DC = Continuous Operation C.T. = Curve Tracer P = 300µs Pulse 2% Duty Cycle	
4.1.0	Static	
4.1.1	$I_{CEX} = 50\mu A$	$V_{CE} = 60V$, $V_{BE} = -0.5V$, $T_C = 150^oC$, Techniques - C.T.

Item	Test Methods and Test Conditions
4.1.2 $I_{CEX} = 10\mu A$	$V_{CE} = 100V$, $V_{BE} = -0.5V$ Technique - C.T.
4.1.3 $I_{CBO} = 50\mu A$	$V_{CB} = 60V$, $T_C = 150^{o}C$ Technique - C.T.
4.1.4 $I_{CBO} = 0.1\mu A$	$V_{CB} = 60V$ Technique - C.T.
4.1.5 $I_{EBO} = 10\mu A$	$V_{EB} = 8V$ Technique - C.T.
4.1.6 $I_{EBO} = 0.1\mu A$	$V_{EB} = 5V$ Technique - C.T.
4.1.7 $V_{(BR)CEO} = 80V$ min	$I_C = 10mA$ Technique - C.T.
4.1.8 $V_{(BR)CEO} = 70V$ min	$I_C = 0.1A$ Technique - C.T.
4.1.9 $I_{CEO} = 100\mu A$	$V_{CEO} = 50V$ Technique - C.T.
4.1.10 $h_{FE} = 30$ min 120 max	$V_{CE} = 2V$, $I_C = 10mA$ Technique - P
4.1.11 $h_{FE} = 40$ min 120 max	$V_{CE} = 2V$, $I_C = 1A$ Technique - P
4.1.12 $h_{FE} = 15$ min 60 max	$V_{CE} = 2V$, $I_C = 1A$, $T_C = -55^{o}C$ Technique - P
4.1.13 $h_{FE} = 60$ min 200 max	$V_{CE} = 2V$, $I_C = 1A$, $T_C = 150^{o}C$ Technique - P
4.1.14 $h_{FE} = 15$ min 45 max	$V_{CE} = 5V$, $I_C = 5A$ Technique - P

Item	Test Methods and Test Conditions
4.1.15 $V_{CE(sat)}$ = 0.25V max	I_C = 1A, I_B = 0.1A Technique - C.T.
4.1.16 $V_{CE(sat)}$ = 2.0V max	I_C = 5A, I_B = 0.5A Technique - C.T.
4.1.17 $V_{BE(sat)}$ = 1.2V max	I_C = 1A, I_B = 0.1A Technique - C.T.
4.1.18 $V_{BE(sat)}$ = 2V max	I_C = 5A, I_B = 0.5A Technique - C.T.
4.1.19 V_{BE} = 1.2V max	V_{CE} = 2V, I_C = 1A Technique - C.T.
4.2.0 Dynamic	
4.2.1 t_{ON} = 300ns	V_{CC} = 20V, I_C = 1A
4.2.2 t_{OFF} = 2.0µs	I_{B1} = - I_{B2} = 100mA
4.2.3 $\lvert h_{FE} \rvert$ = 2 min = 9 max	V_{CE} = 10V, I_C = 1A, f = 10MHz
4.2.4 C_{obo} = 150 pF max	V_{CB} = 10V, f = 1MHz
5.0.0 Thermal Characteristics	
5.1.0 τ_J = 5ms min	MIL-STD-750, method 3146.1 V_{CE} = 10V, I_C = 2A, T_C = 25°C
5.2.0 θ_{J-C} = 3.33°C/W	MIL-STD-750A, method 3136 V_{CE} = 5V, I_C = 2A

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^{\circ}C$, $I_C \geq I_{CEO}$

Test Circuit: JS-6-T12

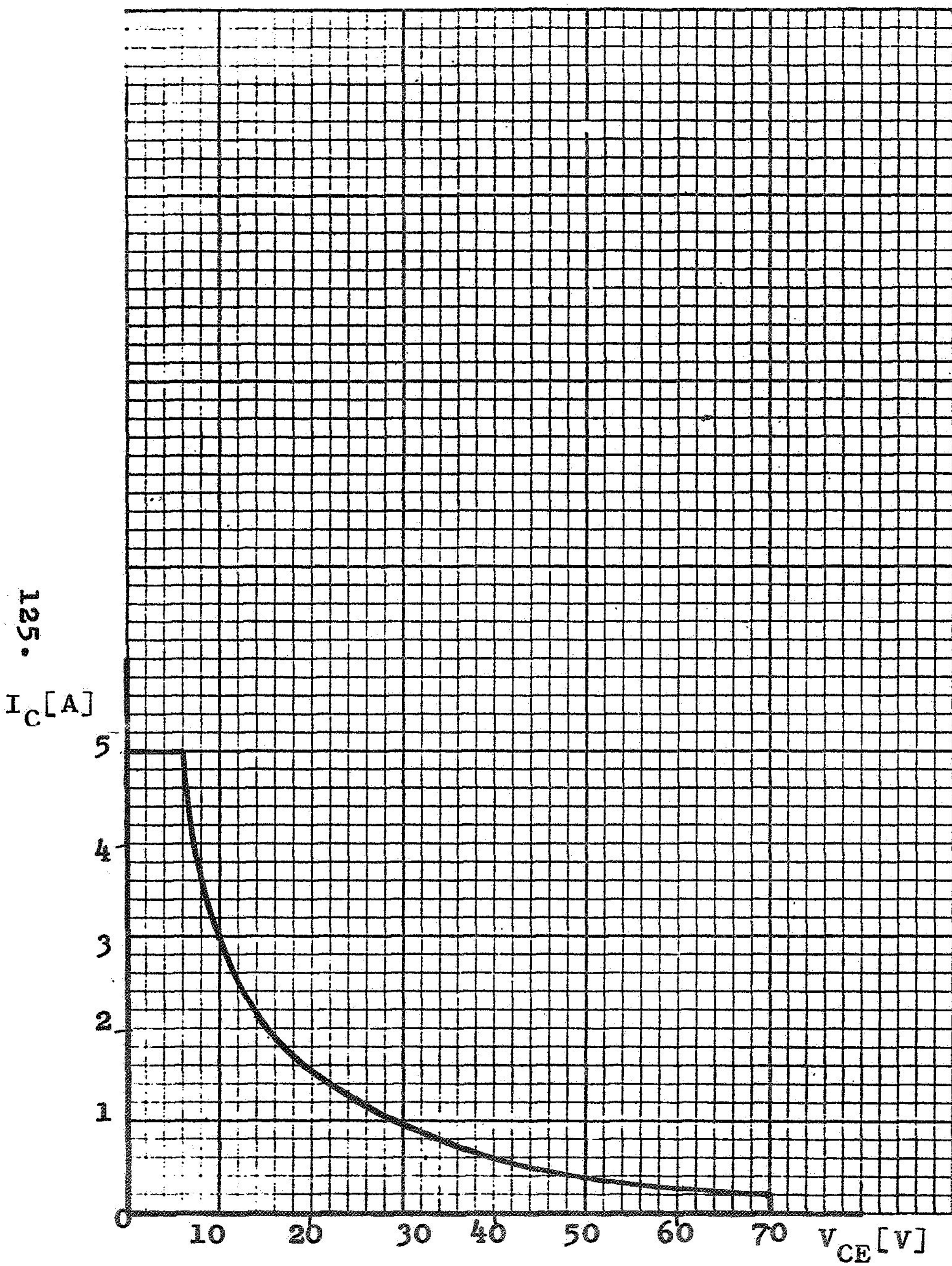


Figure 1

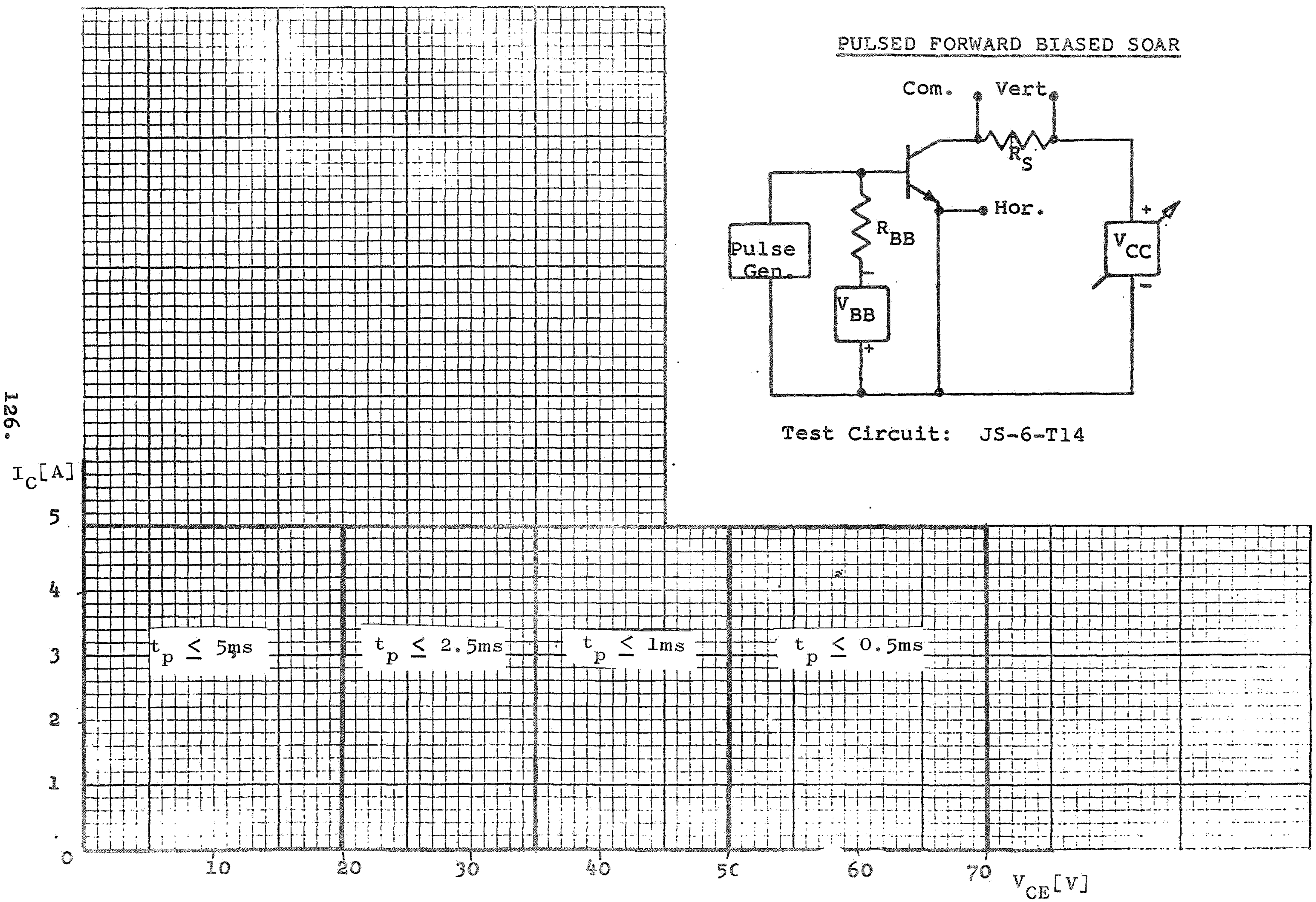

PULSED FORWARD BIASED SOAR
Com.
Vert.
R_S
Hor.
Pulse Gen.
R_{BB}
V_{BB}
V_{CC}
Test Circuit: JS-6-T14
I_C[A]
5
4
3
2
1
0
10
20
30
40
50
60
70
V_{CE}[V]
$t_p \leq 5ms$
$t_p \leq 2.5ms$
$t_p \leq 1ms$
$t_p \leq 0.5ms$

Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

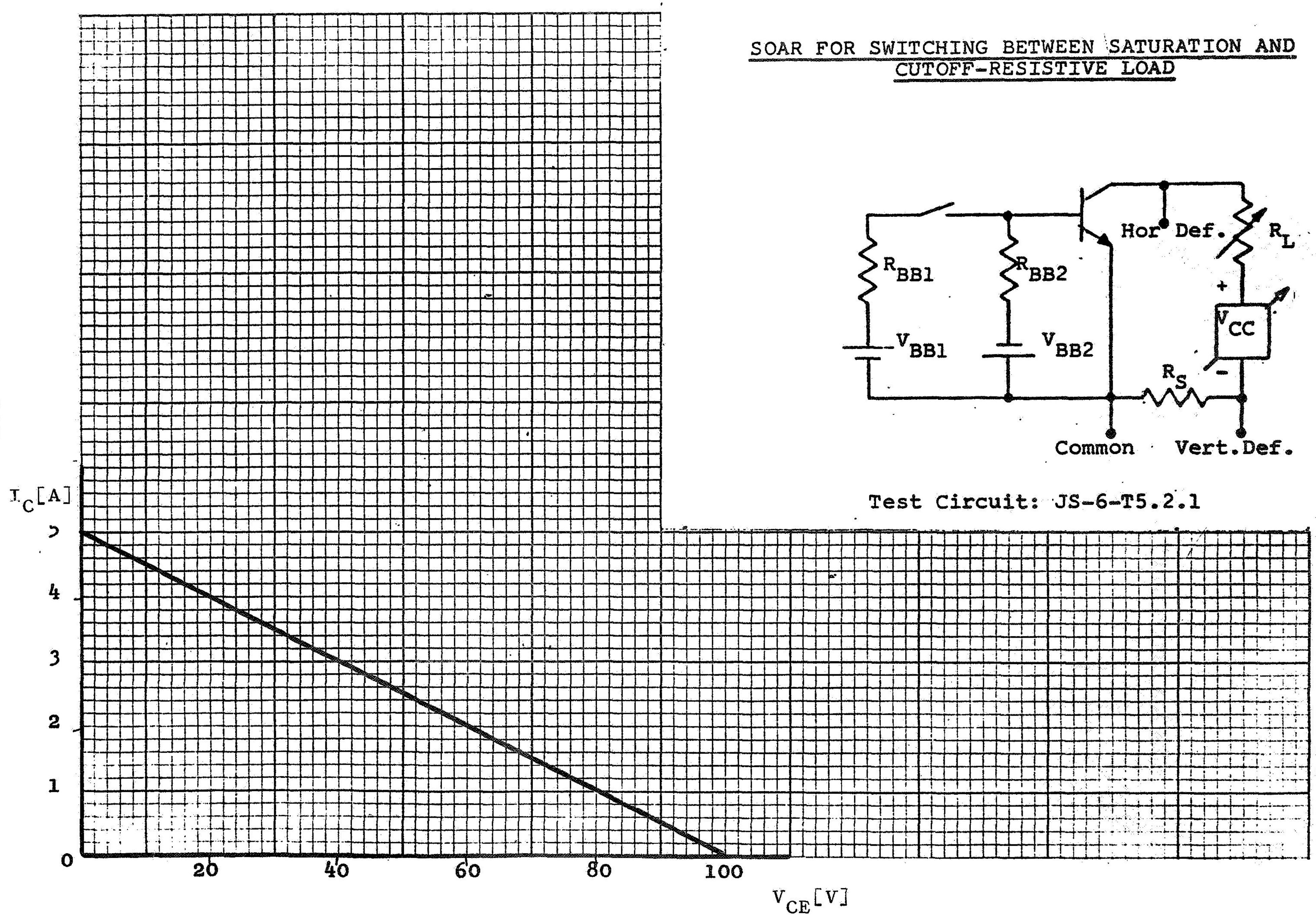
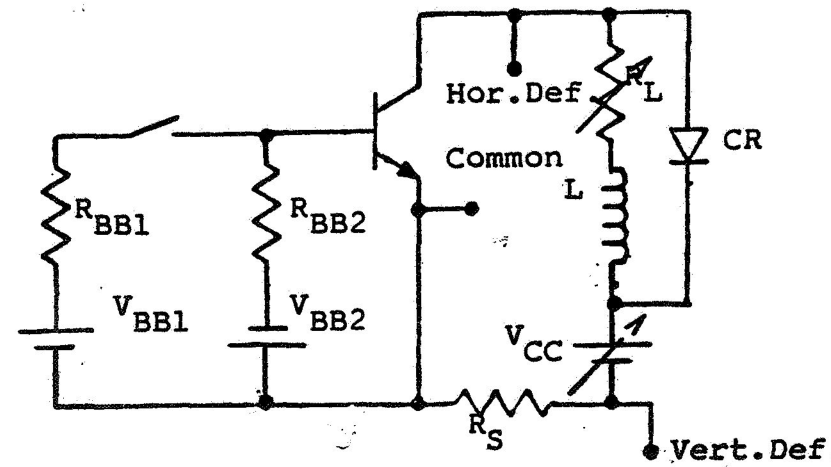
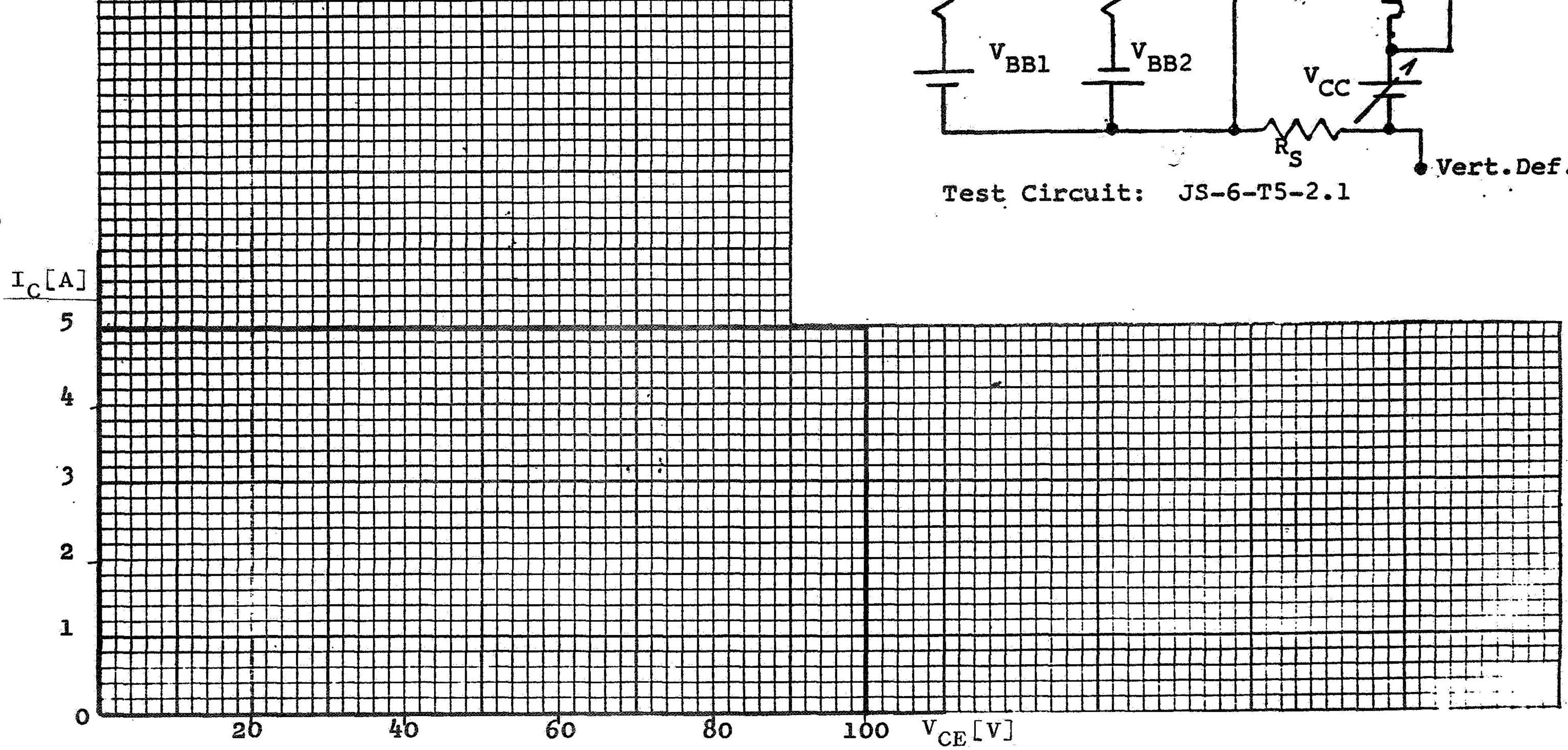


Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD

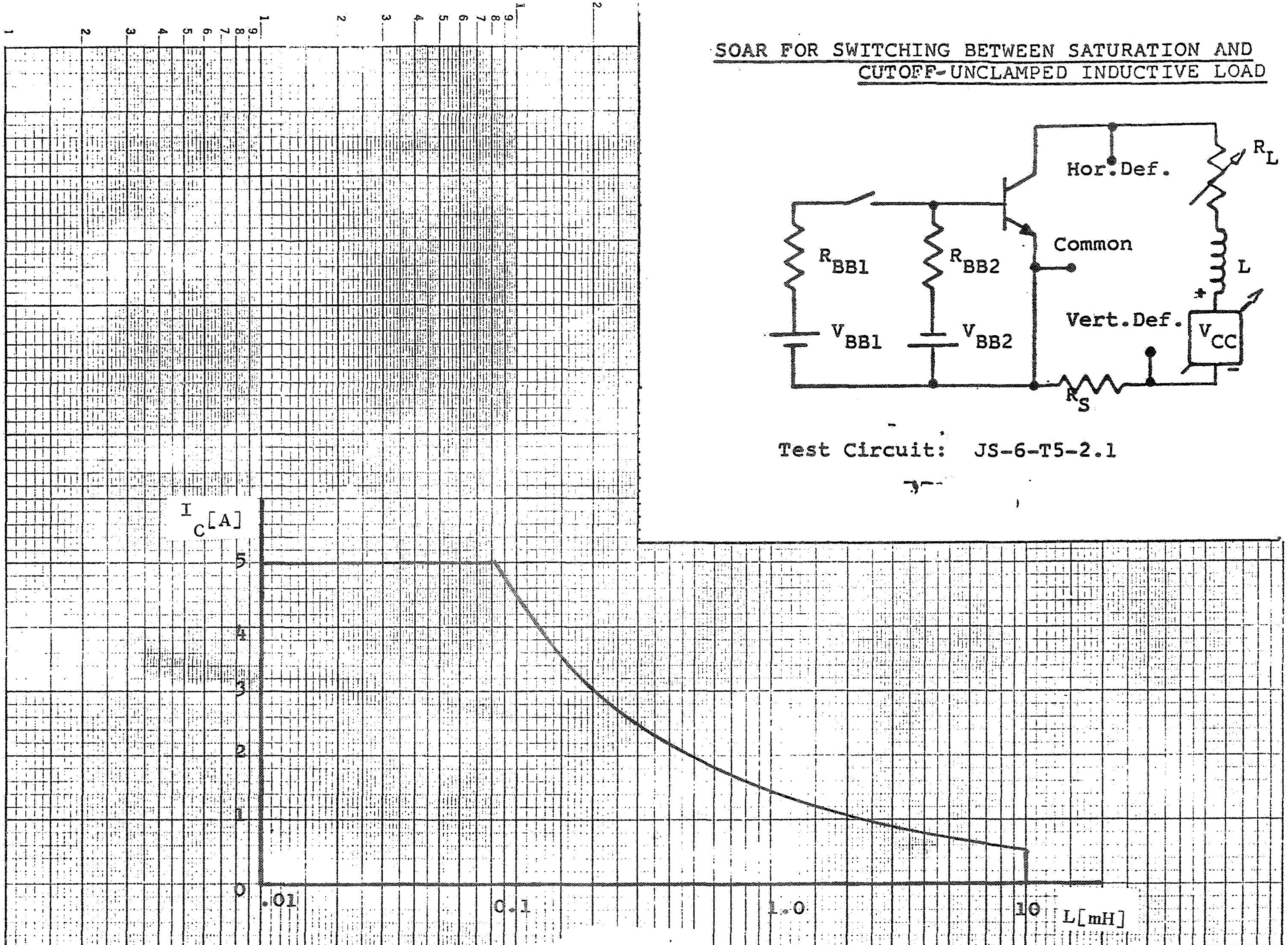


Test Circuit: JS-6-T5-2.1



F... re

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

Figure 5

SHORTED CLASS B SOAR

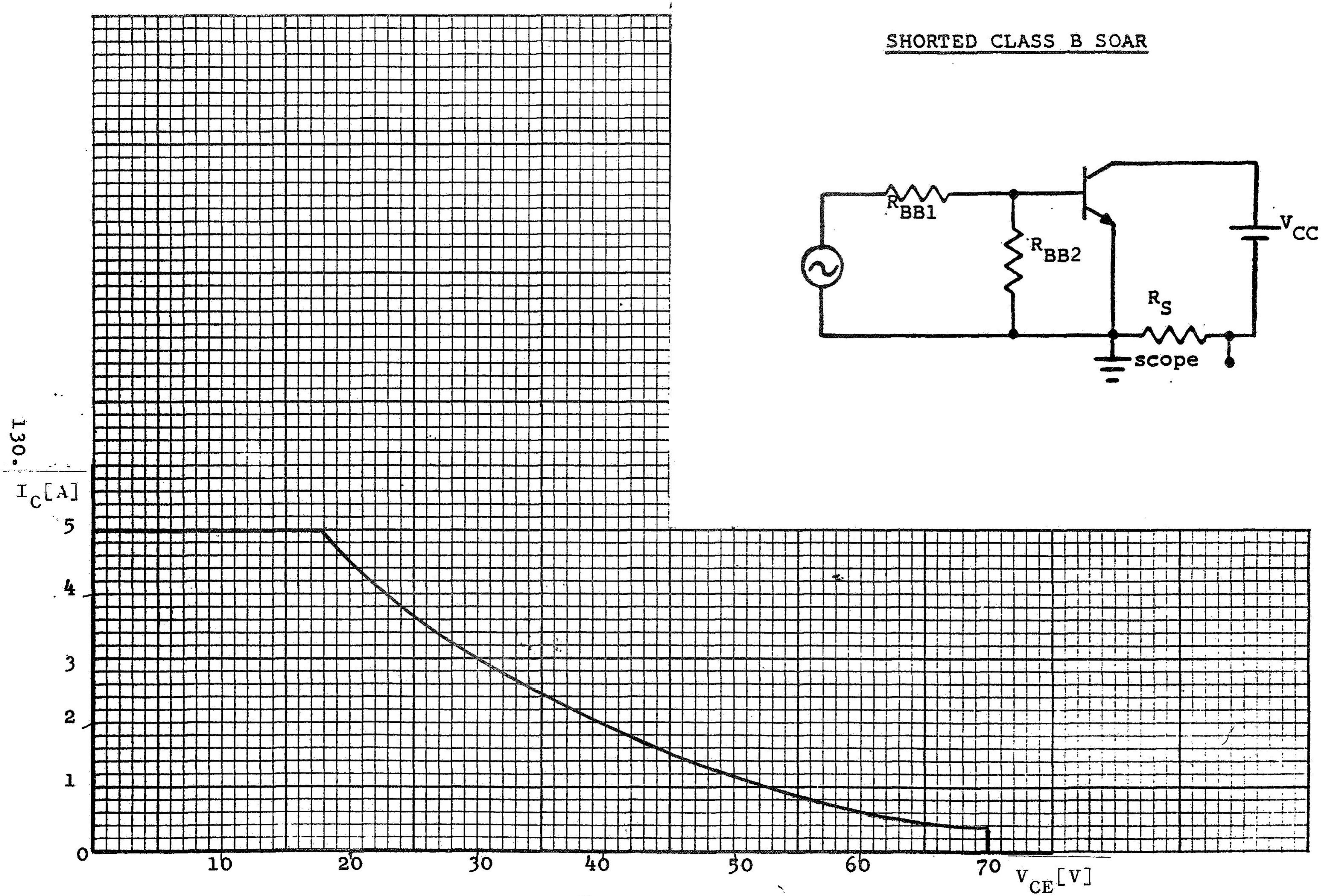


Figure 6

-- TEST REPORT --

SILICON POWER TRANSISTOR

< S2N4150 >

SAFE OPERATING AREA
DETERMINATION FOR PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer H --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item		Test Methods and Test Condition
1.0.0	General Description	
1.1.0	Type -- NPN	
1.2.0	Material -- Silicon	
2.0.0	Mechanical Data	
2.1.0	Outline TO-5	
2.2.0	Terminal Designation	
	1 --- Base	
	2 --- Emitter	
	3 --- Collector	
	Case--Collector	
3.0.0	Maximum Ratings	
3.1.0	Temperature	
3.1.1	$T_{STG(min)} = -55^{o}C$	JS-6-T1.1 [JEDEC Suggested standard: "Test Procedure for Verification of Maximum Ratings." JEDEC Publication No. 65.]
	$T_{STG(max)} = +200^{o}C$	JS-6-T1.2
3.1.2	$T_{J(max)} = +200^{o}C$	JS-6-T2 or MIL-STD-750A Method 3051 $T_C = 100^{o}C$, $P_T = 5W$, $I_C = 0.1A$, $V_{CE} = 50V$
3.1.3	T (Lead) = $230^{o}C$	Distance from Case 1/16" Time = 3 sec.
3.2.0	Voltage	

Item		Test Methods and Test Conditions
3.2.1	$V_{(BR)CBO} = 120V$	JS-6-T3 or MIL-STD-750A Method 3001.1
3.2.2	$V_{(BR)EBO} = 7V$	JS-6-T4 or MIL-STD-750A Method 3026.1
3.2.3	$V_{(BR)CEX} = 70V$	JS-6-T5.1 or MIL-STD-750A Method 3053 $I_C \leq 10A$, $V_{CE} = 70V$, $R_{BB1} = 10\Omega$, $R_{BB2} = 20\Omega$. $V_{BB1} = 16V$, $V_{BB2} = 5.0V$ $R_L = 7\Omega$, $L^* = 1.0mH$ $R_S = 0.1\Omega$ $t_r \leq 10\mu s$, $t_f \leq 10\mu s$, $t_p = 300\mu s$ Duty cycle $\leq 0.2\%$ *J.W. Miller: 7871 in series with 7825-3
3.3.0	Current	
3.3.1	$I_C = 3.0A$	JS-6-T-6 $I_B = 0.3A$, $T_C = 25^oC$
3.3.2	$I_{CM} = 10A$	JS-6-T7 $T_C = 25^oC$ $R_S = 0.1\Omega$ $V_{BB} = 5V$ $R_{BB} = 20\Omega$ $I_B = 1A$, $t_p = 300\mu s$ $d \leq 0.2\%$ $t_r \leq 10\mu s$, $t_f \leq 10\mu s$
3.3.3	$I_B = 0.5A$	JS-6-T8 $T_C = 25^oC$

Item	Test Methods and Test Conditions
3.3.4 $I_{BM} = 1.0A$	JS-6-T4
	$T_C = 25^oC$, $R_S = 1.0\Omega$,
	$t_p = 300\mu s$, $t_r \leq 10\mu s$
	$t_f \leq 10\mu s$, $d \leq 0.2\%$
3.3.5 $I_E = 3.3A$	JS-6-T10
	$I_B = 0.3A$, $T_C = 25^oC$
3.3.6 $I_{EM} = 11A$	[see 3.3.2]
3.4.0 Power	
3.4.1 $P_T = 5.0W$	JS-6-T12
	Test Point:[See 3.1.2]
3.4.2 $P_{TM} = I_C\ V_{CC} = 700W$	JS-6-T13 or MIL-STD-750A
	Method 3052
	$T_C = 100^oC$, $V_{CC} = 70V$,
	$V_{BB1} = 16V$, $R_{BB} = 10\Omega$,
	$I_C = 10A$, Pulse Width = $100\mu s$
	Duty Cycle $\leq 0.2\%$ $t_r \leq 10\mu s$
	$t_f \leq 10\mu s$
3.5.0 Maximum Operating Conditions	
3.5.1 Forward Biased Continuous DC-SOAR	JS-6-T12 or MIL-STD-750A
	Method 3051
	Test Points: [See 3.1.2]

Item		Test Methods and Test Conditions
3.5.2	Pulsed Forward Biased SOAR	JS-6-T14 or MIL-STD-750A Method 3052 Test Points: $T_C = 100^oC$, $V_{BB} = 5V$, $R_{BB} = 20\Omega$, $t_r \leq 10\mu s$, $t_f \leq 10\mu s$, $I_C = 10A$, Duty Cycle $\leq 0.2\%$, $R_S = 0.1\Omega$, 1. $t_p = 100\mu s$: $V_{CC} = 70V$ 2. $t_p = 200\mu s$: $V_{CC} = 50V$ 3. $t_p = 300\mu s$: $V_{CC} = 30V$
3.6.0	SOAR Switching between Saturation and Cutoff	
3.6.1	Resistive Load	JS-6-T5-5.1 or MIL-STD-750A Method 3053 with L = 0 and CR disconnected Test Points: $R_{BB1} = 10\Omega$, $R_{BB2} = 20\Omega$, $V_{BB1} = 16V$, $V_{BB2} = 5.0V$, $T_C = 100^oC$, $t_f \leq 10\mu s$, $t_r \leq 10\mu s$, $R_S = 0.1\Omega$, $R_L = 12\Omega$, $V_{CC} = 120$, $d \leq 0.2\%$, $t_p \leq 300\mu s$
3.6.2	Clamped Inductive Load	JS-6-T5.1 or MIL-STD-750A Method 3053 Test Point: [see 3.2.3]

Item	Test Methods and Test Conditions
3.6.3 Unclamped Inductive Load	JS-6-T5.1 or MIL-STD-750A
	Method 3053 and CR disconnected

Test Points:

1. $V_{BB1} = 16V$ $L^* = 1.0mH$
   $R_{BB1} = 10\Omega$ $R_L = .35\Omega$
   $V_{BB2} = 5.0V$ V_{CC} = adjust to
   $I_C = 10A$
   $R_{BB2} = 20\Omega$ $t_p = 300\mu s$
   $R_S = 0.1\Omega$ $d \leq 0.2\%$

*J.W.Miller:7871 in series with 7825-3

2. $V_{BB1} = 6.0V$ $L^* = 10mH$
   $R_{BB1} = 10\Omega$ $R_L = .11\Omega$
   $V_{BB2} = 5.0V$ V_{CC} = adjust to
   $d \leq 0.2\%$ $I_C = 0.5A$
   $R_{BB2} = 20\Omega$ $t_p = 300\mu s$

*Chicago Standard Transformer Corp.
C-2688

3.7.0 Shorted Class B SOAR	[See Figure 6]

Test Points:

$I_{C(peak)} = 0.43A$, $V_{CC} = 35V$

$R_S = 0.1\Omega$, $R_{BB1} = 10\Omega$, $R_{BB2} = 20\Omega$

$f = 20Hz$, $T_C = 100^oC$

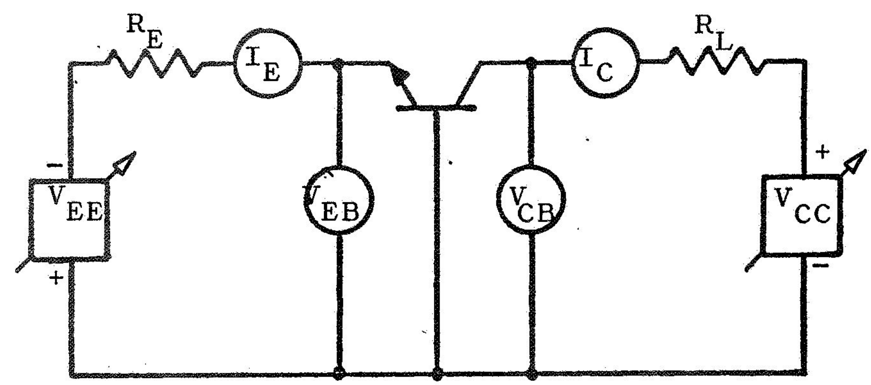
Item		Test Methods and Test Conditions
4.0.0	Electrical Characteristics	
	Maximum limits unless otherwise noted.	$T_C = 25^{o}C$ [unless otherwise noted]
	Technique:	
	MIL-STD-750A * JS-6	
	C.T. = Curve Tracer	
	P = 300µs Pulse 2% Duty Cycle	
4.1.0	Static	
4.1.1	I_{CBO} = 100nA max	V_{CB} = 80V, Technique *Method 3036.1D
4.1.2	I_{CBO} = 10µA max	V_{CB} = 80V, $T_C = 150^{o}C$ Technique *Method 3036.1 D
4.1.3	I_{CBO} = 10µA max	V_{CB} = 100V, Technique *Method 3036.1 D
4.1.4	I_{CEV} = 100µA max	V_{CE} = 60V, V_{EB} = 0.5V, $T_C = 150^{o}C$ Technique *Method 3041.1A
4.1.5	I_{CEO} = 10µA max	V_{CE} = 60V, Technique *Method 3041.1 A
4.1.6	I_{EBO} = 10µA max	V_{EB} = 5V, Technique *Method 3061.1 D
4.1.7	V_{CEO} = 70V min	I_C = 100ma, Technique C.T. [half wave]
4.1.8	h_{FE} = 40 min 145 max	I_C = 10mA, V_{CE} = 5V Technique C.T.
4.1.9	h_{FE} = 45 min 170 max	I_C = 100mA, V_{CE} = 5V Technique P
4.1.10	h_{FE} = 50 min 175 max	I_C = 1.0A, V_{CE} = 5V Technique P

Item	Test Methods and Test Conditions
4.1.11 h_{FE} = 40 min 120 max	I_C = 5.0A, V_{CE} = 5V Technique P
4.1.12 h_{FE} = 10 min	I_C = 10A, V_{CE} = 5V Technique P
4.1.13 h_{FE} = 75 min 350 max	I_C = 100mA, V_{CE} = 5V, T_C = 150°C Technique P
4.1.14 h_{FE} = 70 min 320 max	I_C = 1.0A, V_{CE} = 5V, T_C = 150°C Technique P
4.1.15 h_{FE} = 30 min 150 max	I_C = 5.0A, V_{CE} = 5V, T_C = 150°C Technique P
4.1.16 h_{FE} = 30 min 90 max	I_C = 100mA, V_{CE} = 5V, T_C = -55°C Technique P
4.1.17 h_{FE} = 30min 100 max	I_C = 1.0A, V_{CE} = 5V, T_C = -55°C Technique P
4.1.18 h_{FE} = 20 min 75 max	I_C = 5.0A, V_{CE} = 5V, T_C = -55°C Technique P
4.1.19 $V_{CE(S)}$ = 0.55V max	I_C = 5.0A, I_B 0.5A Technique * P
4.1.20 $V_{CE(S)}$ = 2.0V max	I_C = 10A, I_B = 1.0A Technique* P
4.1.21 $V_{BE(S)}$ = 1.4V max	I_C = 5.0A, I_B = 0.5A Technique* P
4.1.22 $V_{BE(S)}$ = 2.0V max	I_C = 10A, I_B = 1.0A Technique* P

Item		Test Methods and Test Conditions
4.2.0	Dynamic	
4.2.1	h_{FE} = 1.5 min 8.0 max	I_C = 200mA, V_{CE} = 10V, f = 10MHz
4.2.2	C_{obo} = 350 pF max	V_{CB} = 10V, I_E = 0 f = 1MHz
4.2.3	t_{ON} = 0.5µs max	circuit specified with registered spec. S2N4150
4.2.4	t_{OFF} = 2.5µs max	Circuit specified with registered spec. S2N4150
5.0.0	Thermal Characteristics	
5.1.1	τ_J = 20 ms min	
5.1.2	θ_{JC} = 20 ^{o}C/W max	
5.1.3	θ_{JA} = 175^{o}C/W max	

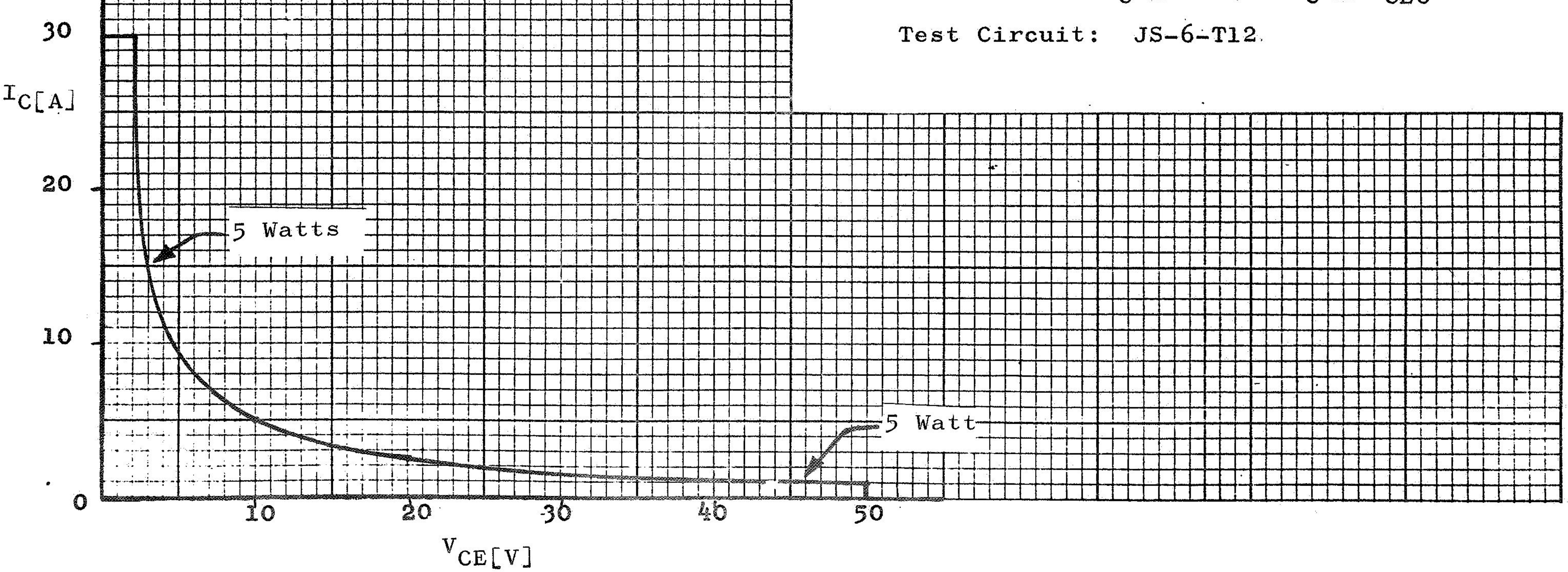
*Test clips 1/4" from case

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^{o}C$, $I_C \geq I_{CEO}$

Test Circuit: JS-6-T12



PULSED FORWARD BIASED SOAR

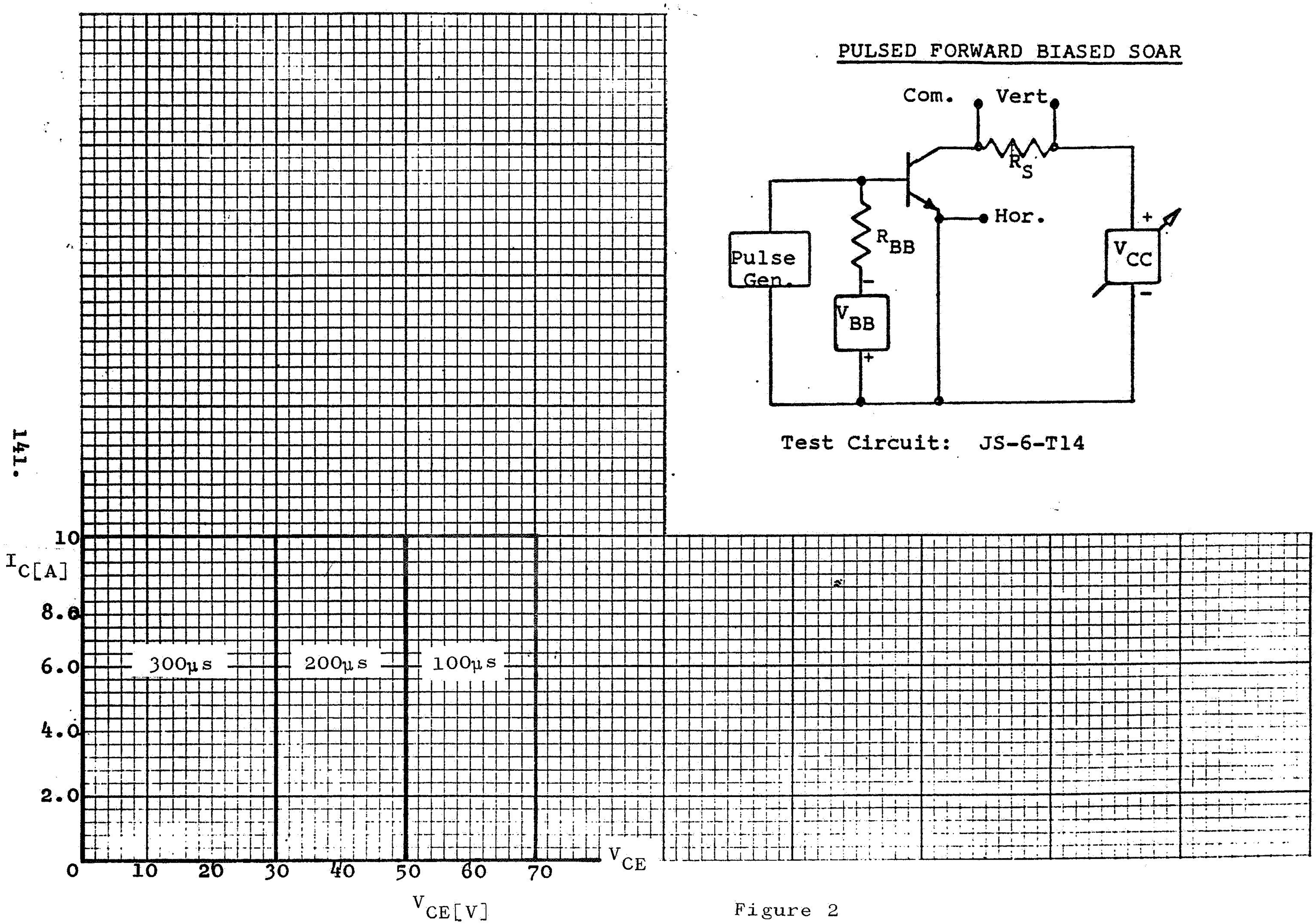


Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

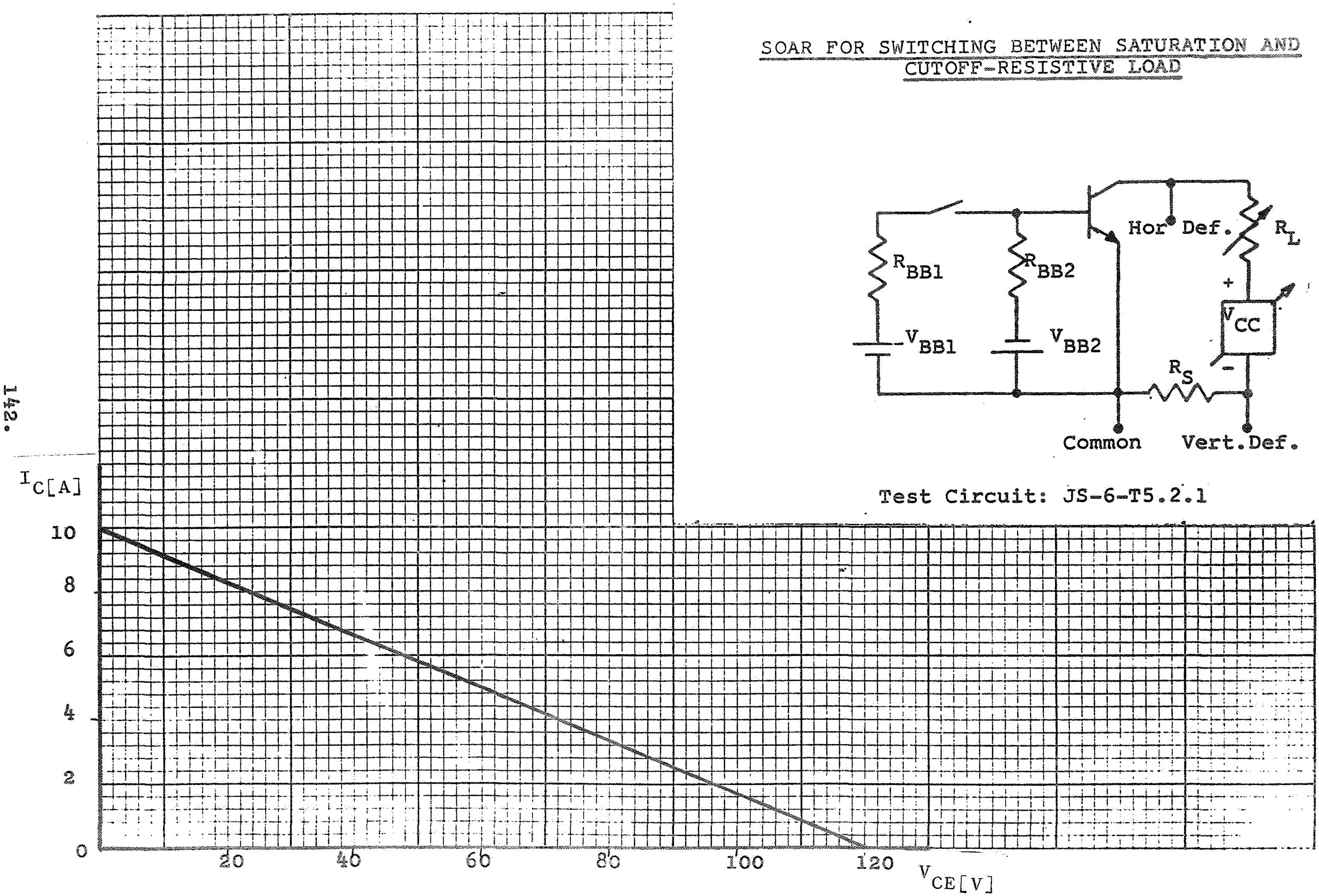
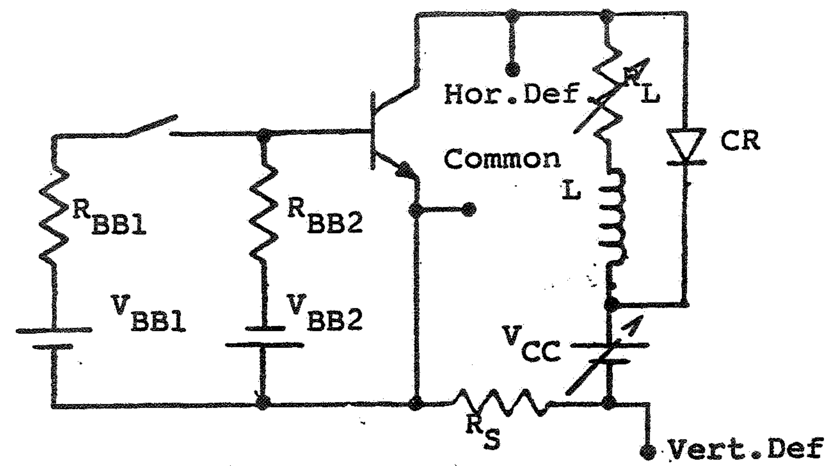
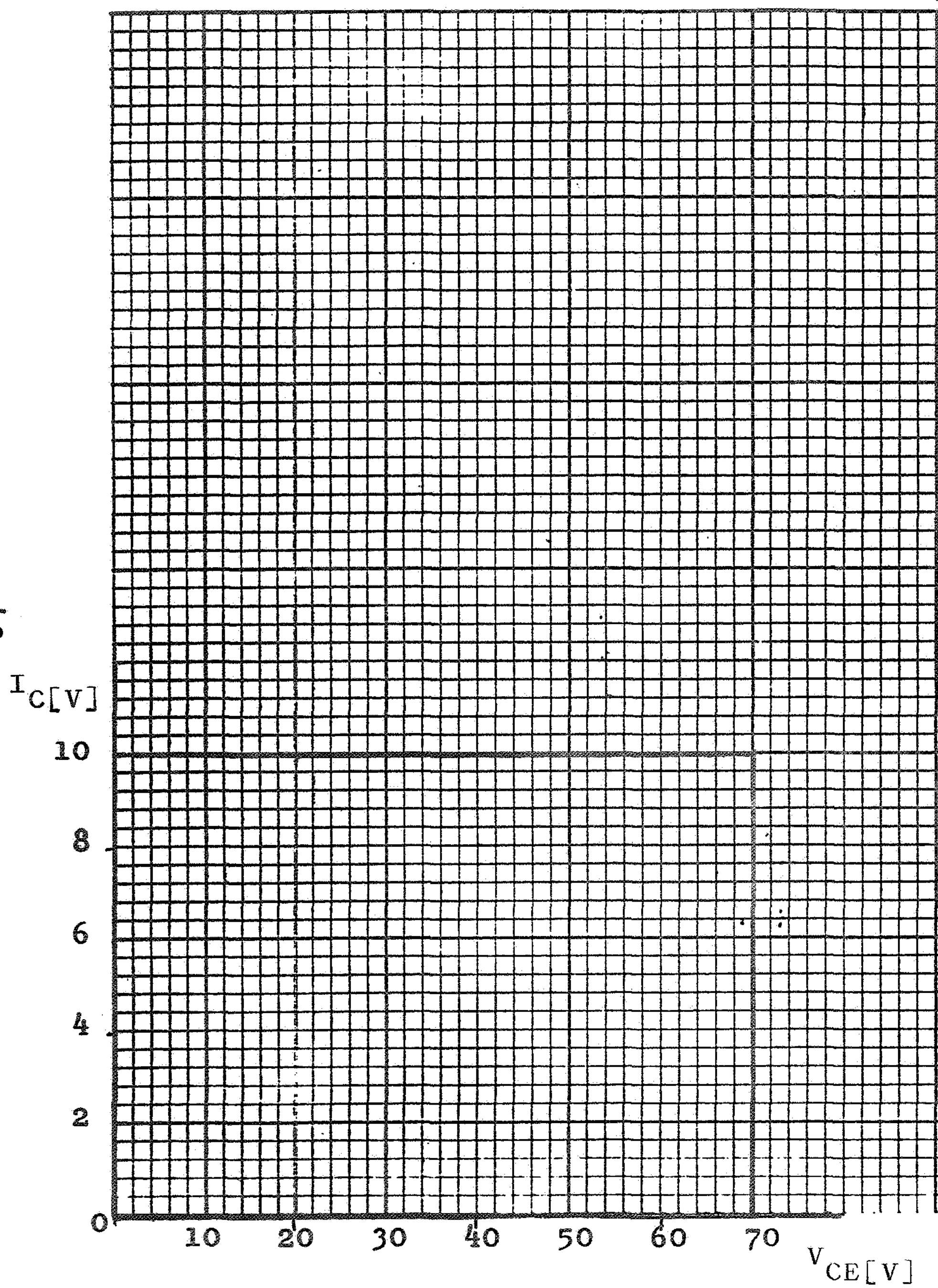


Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1



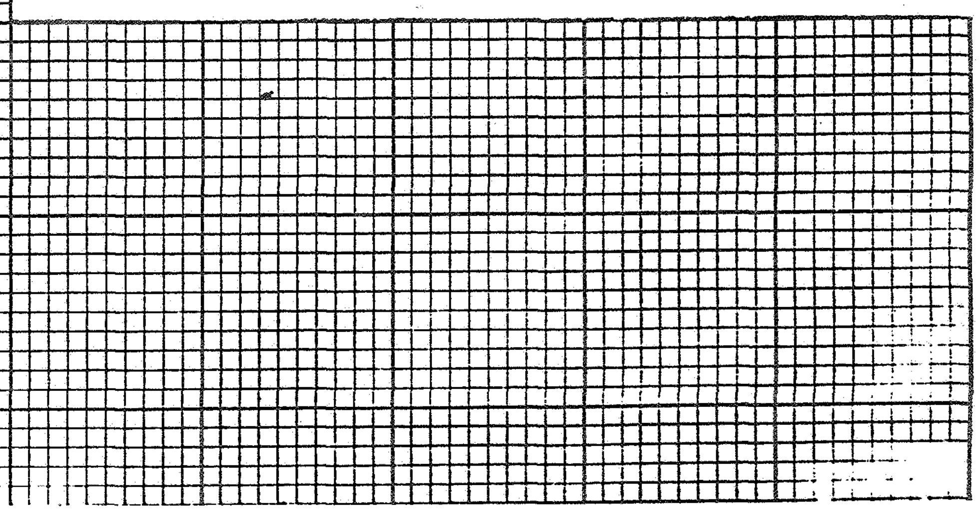


Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD

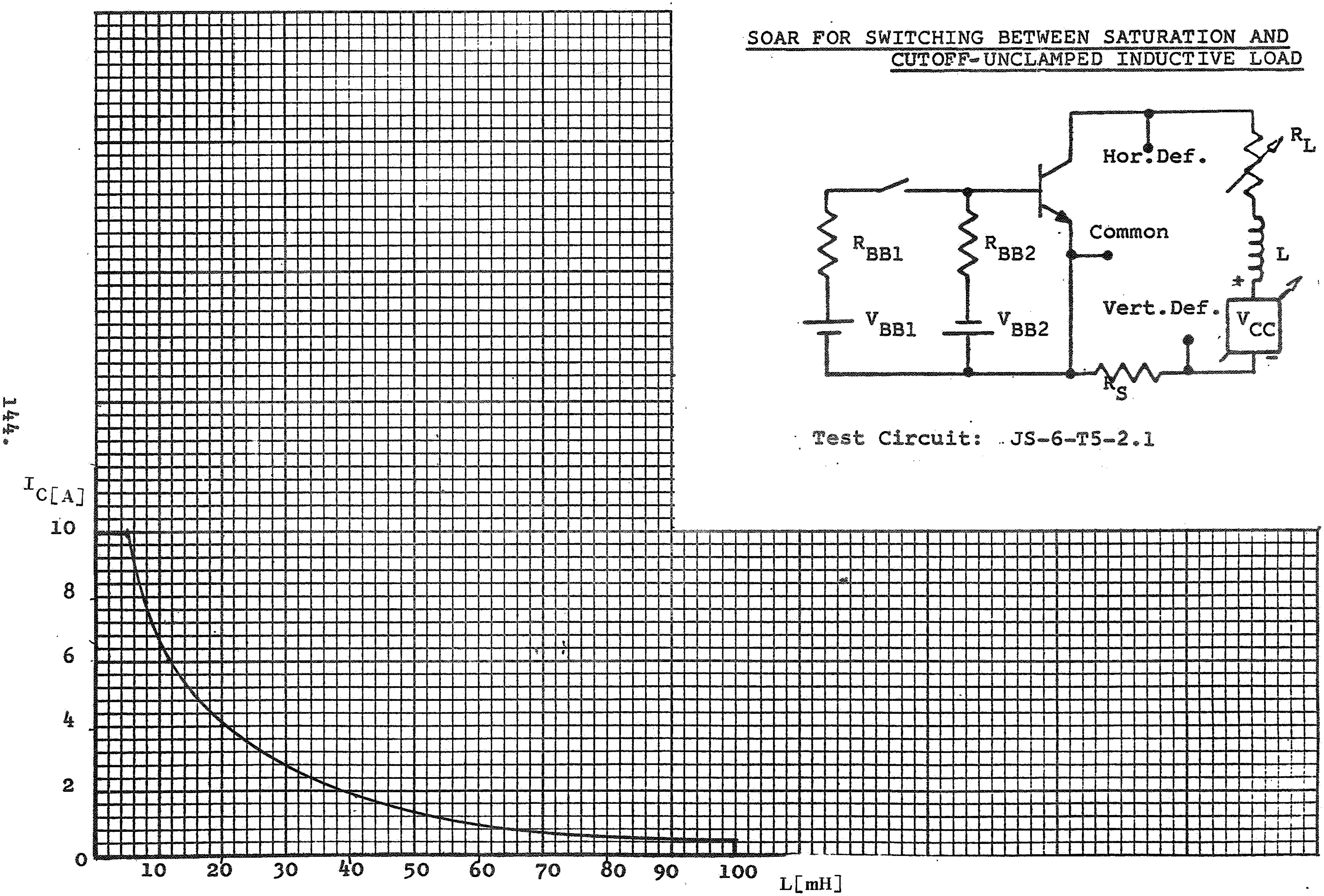


Figure 5

SHORTED CLASS B SOAR

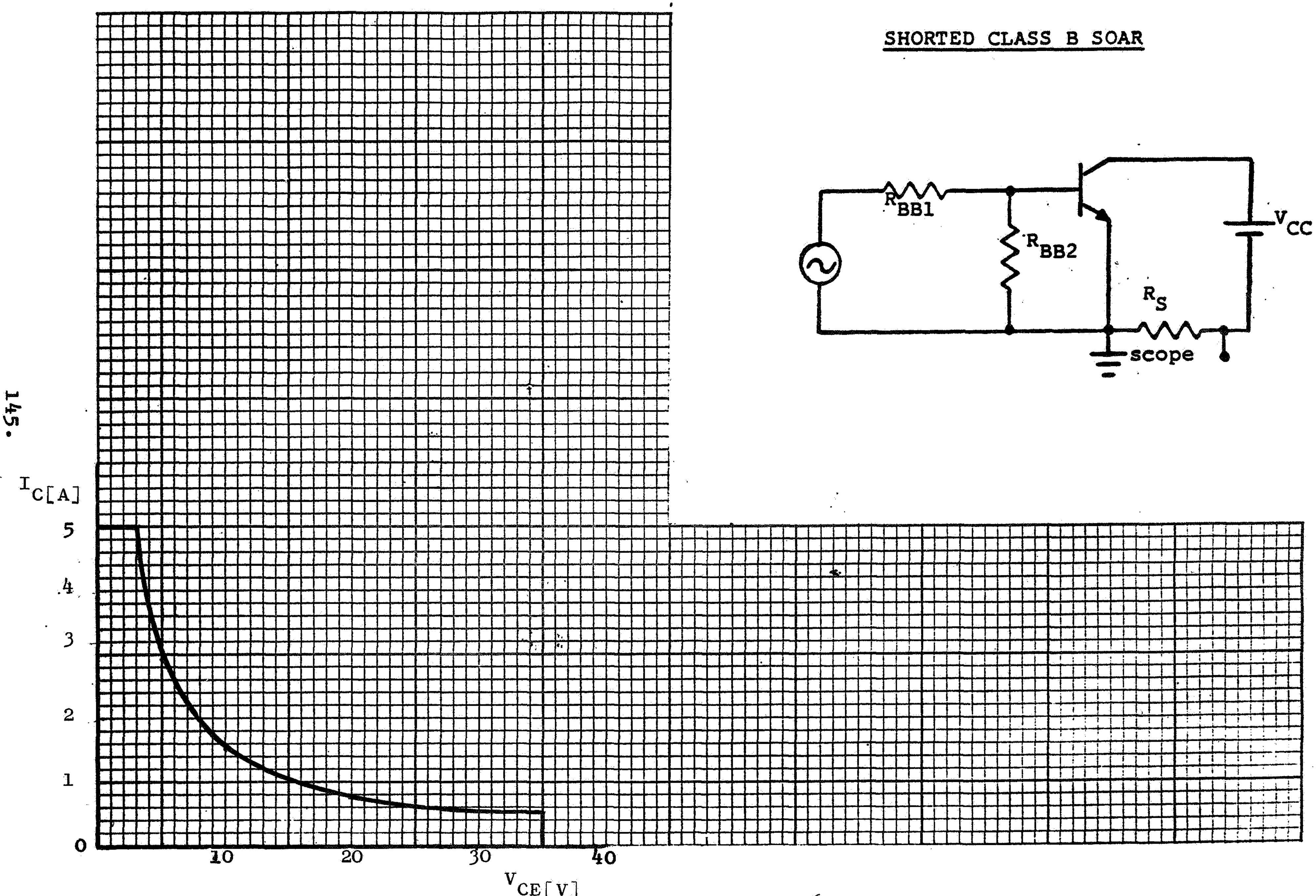


Figure 6

-- TEST REPORT --

SILICON POWER TRANSISTOR

< 2N5559 >

EXAMPLE DEVICE SPECIFICATIONS

-- Manufacturer Bendix --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

The format used in the presentation of this data was recently developed for the registration of transistor specifications.

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item	Registered Data	Test Methods & Test Conditions	Remarks
1.0.0	GENERAL DESCRIPTION		Triode Transistor, Power Switching
1.1.0	Type: NPN		NPN, PNP, etc.
1.2.0	Material: Silicon		Ge., Si., etc.
2.0.0	MECHANICAL DATA		Note 1
2.1.0	Outline: TO-3		Note 2
2.2.0	Terminal Designation		Indicate all unconnected terminals as "NC".
	1: Base		
	2: Emitter		
	3:		
	case: Collector		Indicate "I" if all leads insulated from case.
3.0.0	MAXIMUM RATINGS		Note 3
3.1.0	Temperature		
3.1.1	T_{stg} (max): 200 °C	JS-6-T1.2	Test Methods JS-6-T___ see "Test Procedures for Verification of Maximum Ratings of Power Transistors". JEDEC Publication No. 65
	T_{stg} (min): -65 °C	JS-6-T1.1	
3.1.2	$T_{J(max)}$: 200 °C	JS-6-T2	
		T_C: 150 °C	T_C = 75% to 90% T_J Max
		V_{CB}: ≈ 20 V; I_C: 2.5 A	
3.1.3	T (Lead): 235 °C	Distance from case: 1/32 in.	Item 3.1.3 is not required on transistors whose storage temperature is sufficiently high so that the lead temperature test becomes redundant.
		Time: 10 s	

Item	Registered Data		Test Methods & Test Conditions	Remarks
3.2.0	Voltage		$T_C = 25°C$	
3.2.1	V_{CBO}	150 V	JS-6-T3	
3.2.2	V_{EBO}	7 V	JS-6-T4	
3.2.3	V_{CEX}	120 V	JS-6-T5.1	Inductive Method
			I_C ($V_{CE} = V_{CEX}$) 10 A	R_{BB2} may be infinite
			V_{CC} 120 V; R_L 10 Ω	V_{BB2} may be zero
			L 1 mH; CR 1N1204	Equivalent registered type number of CR, if used, must be given.
			V_{BB1} 6.2 V; R_{BB1} 3 Ω	
			V_{BB2} 0 V; R_{BB2} 5 Ω	
			Pulse Width 1 ms; Duty Cycle 2 %	
		or	or	
			JS-6-T5.2	Pulsed Method
		V	I_C A; R_{BB} Ω	R_{BB} may be zero
			$V_{BB(off)}$ V	
			Pulse Width ms; Duty Cycle %	

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.3.0	Current		
3.3.1	I_C 10 A	JS-6-T6 I_B 2 A T_C $\leq$ °C	Continuous collector current
3.3.2	I_{CM} 15 A	JS-6-T7 $T_C = 25°C$ R_S 0.1 Ω V_{BB} 0 V R_{BB} ∞ Ω Input Pulse Characteristics Pulse Amplitude 5A Pulse Width 1000 ms Duty Cycle 1 % t_r $\leq$ 5 μs t_f $\leq$ 5 μs	Peak collector current
3.3.3	I_B 5 A	JS-6-T8 T_C $\leq$ 25 °C	Continuous base current
3.3.4	I_{BM} 7 A	JS-6-T9 $T_C = 25°C$ Input Pulse Characteristics Pulse Width 1000 ms Duty Cycle 10 % t_r $\leq$ 5 μs t_f $\leq$ 5 μs	Peak base current
3.3.5	I_E 12 A	JS-6-T10 I_B 2 A T_C 25 °C	Continuous Emitter current

Item	Registered Data		Test Methods & Test Conditions	Remarks
3.3.6	I_{EM}	[A]	JS-6-T11	
			T_C= 25°C R_S [Ω]	Peak Emitter Current
			V_{BB} [V] R_{BB} [Ω]	
			Input Pulse Characteristics	
			Pulse Width [ms]	
			Duty Cycle [%]	
			t_r [≤ μs] t_f [≤ μs]	
3.4.0	Power			
3.4.1	P_T	[100 W]	JS-6-T12	
			T_C [100 °C]	T_C= 55°C (for device with $T_{J\ (max)} \leq 125°C$)
			V_{CB} [50 V] I_C [2 A]	
	Derating Factor	[1 W/°C]		T_C= 100°C (for devices with $T_{J\ (max)} > 125°C$)
3.4.2	P_{TM}	[900 W]	JS-6-T13	$P_{TM} = I_C\ V_{CC}$
			T_C= 25°C	
			V_{CC} [90 V]	
			V_{BB} [0 V] R_{BB} [5 Ω]	
			Input Pulse Characteristics	
			Pulse Width [0.25 ms]	
			Duty Cycle [1 %]	
			t_r [≤ 5 μs] t_f [≤ 5 μs]	

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.5.0	Maximum Operating Conditions		Refer to Appendix A
3.5.1	DC - Attach drawing of operating area V_{CE} vs I_C	T_C [100 °C] Fig. 1 1. I_C = 0.5A; V_{CE} = 80V 2. I_C = 2A; V_{CE} = 50V	T_C = T_C (3.4.1) The circuit of JS-6-T12 is recommended.
3.5.2	Pulsed (Forward Bias Drive) Attach drawing of operating area. V_{CE} vs I_C for one or more pulse widths	JS-6-T14, T_C = 25°C; Fig. 2 V_{BB} [0 V] R_{BB} [5 Ω] Input Pulse Characteristics Pulse Width [___ ms] Duty Cycle [2 %] t_r [≤ 5 μs] [≤ 5 μs]	Pulse width shall be 1,2,3, or 5 x 10^x sec. Pulse Width [ms] / V_{CC} [V] / I_C [A] 1. 1 ms @ 60 10 2. 0.5 ms @ 80 10 3. 0.25 ms @ 90 10
3.6.0	Maximum Operating Conditions for Switching between Saturation and Cutoff		For example refer to Appendix B Specify 3.6.1 or 3.6.2 or 3.6.3
3.6.1	Resistive Load OR	JS-6-T5.1 with L = 0 and CR disconnected T_C = [25 °C]; Fig. 3 Input Pulse Characteristics Pulse Width [1 ms] Duty Cycle [2 %] t_r [≤ 5 μs] t_f [≤ 5 μs] R_{BB1} [3 Ω] R_{BB2} [5 Ω] V_{BB1} [6.2 V] V_{BB2} [0 V]	Supply graph of Safe Operating Area on the I_C - V_{CE} plane. Safe Operating Area graph must include: V_{CE} (3.2.3) I_C (3.3.1) If one test condition cannot satisfy V_{CE} (3.2.3) and I_C (3.3.1) specify conditions for each test.

37653-- 6- 10

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.6.2	Clamped Inductive Load	JS-6-T5.1 T_C = [25 °C] Fig. 4 Input Pulse Characteristics Pulse Width [1 ms] Duty Cycle [2 %] t_r [≦ 5 µs] t_f [≦ 5 µs] R_{BB1} [3 Ω] R_{BB2} [5 Ω] V_{BB1} [6.2 V] V_{BB2} [0 V] L [1 mH] CR 1N1204 The/JEDEC Type Number of the characteristics must be specified.	Supply graph of Safe Operating Area on the I_C-V_{CE} plane. Safe Operating Area graph must include: V_{CE} (3.2.3) I_C (3.3.1) If one test condition cannot satisfy V_{CE} (3.2.3) and I_C (3.3.1) specify conditions for each test.
	OR		
3.6.3	Unclamped Inductive Load	JS-6-T5.1 and CR Disconnected T_C = [25 °C] Fig. 5 Input Pulse Characteristics Pulse Width [20 ms] Duty Cycle [30 %] t_r [≦ 5 µs] t_f [≦ 5 µs] R_{BB1} [3 Ω] R_{BB2} [5 Ω] V_{BB1} [9.2 V] V_{BB2} [5 V] L [40 mH] Q of L [≧ 1500 @ f = 1 MHz] f_{RESON} of L [≧ 8 MHz] I_C [4.0 A] V_{CC} [22 V]	For L = 6.4 mH; I_C=10 A I_C ≧ I_C (4.1.7)

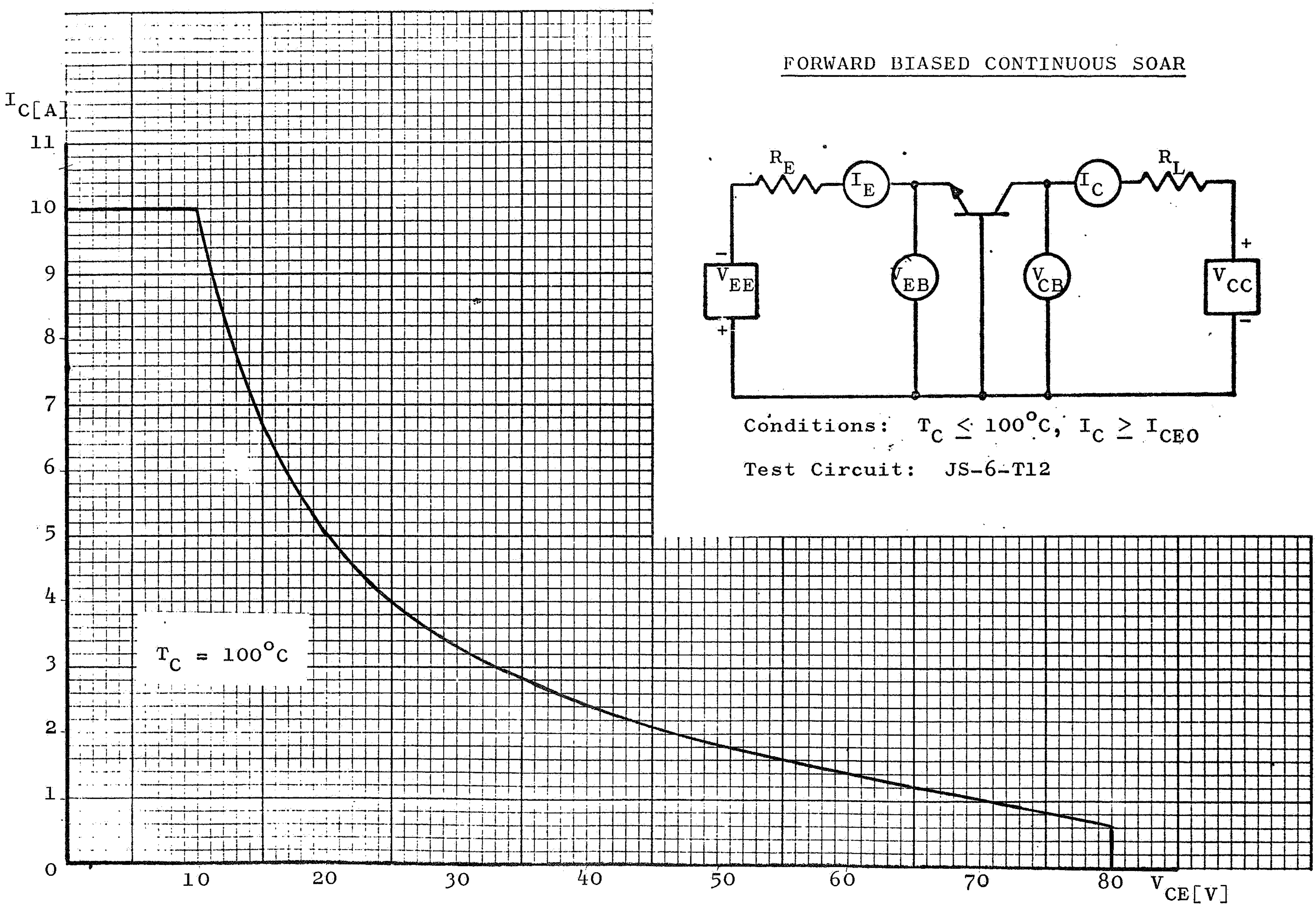
Item	Registered Data	Test Methods & Test Conditions	Remarks
4.0.0	Electrical Characteristics	T_C = 25°C (unless otherwise noted)	Maximum limits unless otherwise noted.
4.1.0	Static		Note 4
4.1.1	I_{CEV} 2 mA	T_C 150 °C V_{CE} 150 V V_{BE} (fwd., rev.) 0 V Technique C.T.	$T_C \geq 1/2\ T_J$ (3.1.2)
4.1.2	I_{CEV} 0.5 mA	V_{CE} 150 V V_{BE} (fwd., rev.) 0 V Technique C.T.	$V_{CE} \geq 0.9\ V_{CBO}$ (3.2.1) Specify 4.1.2 or 4.1.3 and 4.1.4
	or	or	
4.1.3	I_{CBO} mA	V_{CB} V	$V_{CB} = V_{CBO}$ (3.2.1)
	and	and	
4.1.4	V_{EBF} V	V_{CB} V Technique	$V_{CB} = V_{CBO}$ (3.2.1)

Item	Registered Data	Test Methods & Test Conditions	Remarks
4.1.5	I_{EBO} [0.01 mA]	V_{EB} [7 V] Technique [C.T.]	$V_{EB} = V_{EBO}$ (3.2.2)
4.1.6	$V_{(BR)CEO}$ [100 Min V]	I_C [0.2 A] I_B [0 mA] Technique [C.T.]	Note 5
4.1.7	h_{FE} [20 Min] [60 Max]	V_{CE} [2 V] I_C [4 A] Technique [C.T.]	$V_{CE} \leq$ 2.0V or 2 x $V_{CE(sat)}$ (4.1.8) whichever is greater
4.1.8	$V_{CE(sat)}$ [0.75 Max V]	I_C [4 A] I_B [0.4 A] Technique [C.T.]	$I_C = I_C$ (4.1.7) Measured. 0.064 inches from case.
4.1.9	$V_{BE(sat)}$ [1.5 Max V]	I_C [4 A] I_B [0.4 A] Technique [C.T.]	$I_C = I_C$ (4.1.7) Measured 0.064 inches from case.
4.2.0	Dynamic		
4.2.1	t_r [µs]	V_{CC} [ ] I_C [ ] I_{B1} [ ]	Specify 4.2.1, 4.2.2 and 4.2.3 or 4.2.4 and 4.2.5 $I_C = I_C$ (4.1.7) Switching circuit shall be attached. $I_{B1} = I_B$ (4.1.8)
4.2.2	t_s [µs]	V_{CC} [ ] I_C [ ] I_{B1} [ ] I_{B2} [ ]	$I_C = I_C$ (4.1.7) $I_{B1} = I_B$ (4.1.8)
4.2.3	t_f [µs]	V_{CC} [ ] I_C [ ] I_{B1} [ ] I_{B2} [ ]	$I_C = I_C$ (4.1.7) $I_{B1} = I_B$ (4.1.8)
	or		

Item	Registered Data	Test Methods & Test Conditions	Remarks
4.2.4	t_{on} 6.0 µs and	V_{CC} 31V I_C 4A Fig. 6 I_{B1} 0.4A	$I_C = I_C$ (4.1.7) $I_{B1} = I_B$ (4.1.8)
4.2.5	t_{off} 8.0 µs	V_{CC} 31V I_C 4A I_{B1} 0.4A I_{B2} -0.4A	$I_C = I_C$ (4.1.7) $I_{B1} = I_B$ (4.1.8)
4.2.6	f_{hfe} kHz or	I_C A V_{CE} V	Specify 4.2.6 or 4.2.7
4.2.7	$\|h_{fe}\|$ 8 min 40 max	V_{CE} 4 V I_C 1 A	Specify 4.2.6 or 4.2.7
		f 0.1 MHz	Note 6
	ADDITIONAL DATA		
3.6.4	Shorted Class B Safe Operating Area	Fig. 7 $I_{Cpeak} = 1A$ $R_S = 0.1\Omega$; $V_{CC} = 80V$ Input Characteristics $R_{BB1} = 1\Omega$; $R_{BB2} = 3\Omega$ $f = 20$ Hz; $T_C = 100°C$	
3.6.5	$P_T = 120W$	JS-6-T12; $V_{CE} = 60V$; $I_C = 2A$ $t_p = 1s$; $T_A = 25°C$	Single Pulse
3.6.6	$P_T = 120W$	JS-6-T12; $V_{CE} = 8V$; $I_C = 15A$ $t_p = 1s$; $T_A = 25°C$	Single Pulse
4.1.10	$I_{CEO} = 100$ µA max	$V_{CE} = 80V$, Technique C.T.	
4.1.11	$V_{CES} = 125V$ min.	$I_C = 10$ mA; $R_{CC} = 5K\ \Omega$ Technique C.T.	
4.1.12	$V_{EBO} = 7V$ min.	$I_E = 10$ mA; $R_{BB} = 5K\ \Omega$ Technique C.T.	
4.1.13	$h_{FE} = 40$ min.	$I_C = 0.1A$; $V_{CE} = 2V$; Technique C.T.	
4.1.14	$V_{CE(sat)} = 1.2V$ max.	$I_C = 10A$; $I_B = 1A$; Technique C.T.	Measured 0.064 inches from case
4.1.15	$V_{BE(sat)} = 2.0V$ max.	$I_C = 10A$; $I_B = 1A$; Technique C.T.	
4.1.16	$V_{BE} = 1.4V$ max.	$I_C = 4A$; $V_{CE} = 2V$; Technique C.T.	

Item	Registered Data	Test Methods & Test Conditions	Remarks
4.1.17	V_{BE} = 0.55 V min. V_{BE} = 0.65 V max.	I_C = 0.1A; V_{CE} = 2V; Technique C.T.	Measured 0.064" from case
4.1.18	h_{FE} = 40 min.	I_C = 0.5A; V_{CE} = 2V; Technique C.T.	
4.1.19	h_{FE} = 15 min.	I_C = 4A, V_{CE} = 2V; Technique C.T. T_C = $-55^{o}C$	
4.1.20	C_{obo} = 400 pF max.	V_{CB} = 10V; f = 1 MHz	
4.3.0	θ_{JC} = $1^{o}C/W$ max.	I_C = 1A; V_{CE} = 20V	
4.3.1	θ_{JA} = $25^{o}C/W$ max.	I_C = 1A; V_{CE} = 2V	
4.3.2	τ_J = 15 ms	I_C = 1A; V_{CE} = 20V	Time to reach 63% of equilibrium temperature for P_T step input.

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^oC$, $I_C \geq I_{CEO}$

Test Circuit: JS-6-T12

Figure 1

PULSED OPERATION - FORWARD BIASED PULSED SOAR

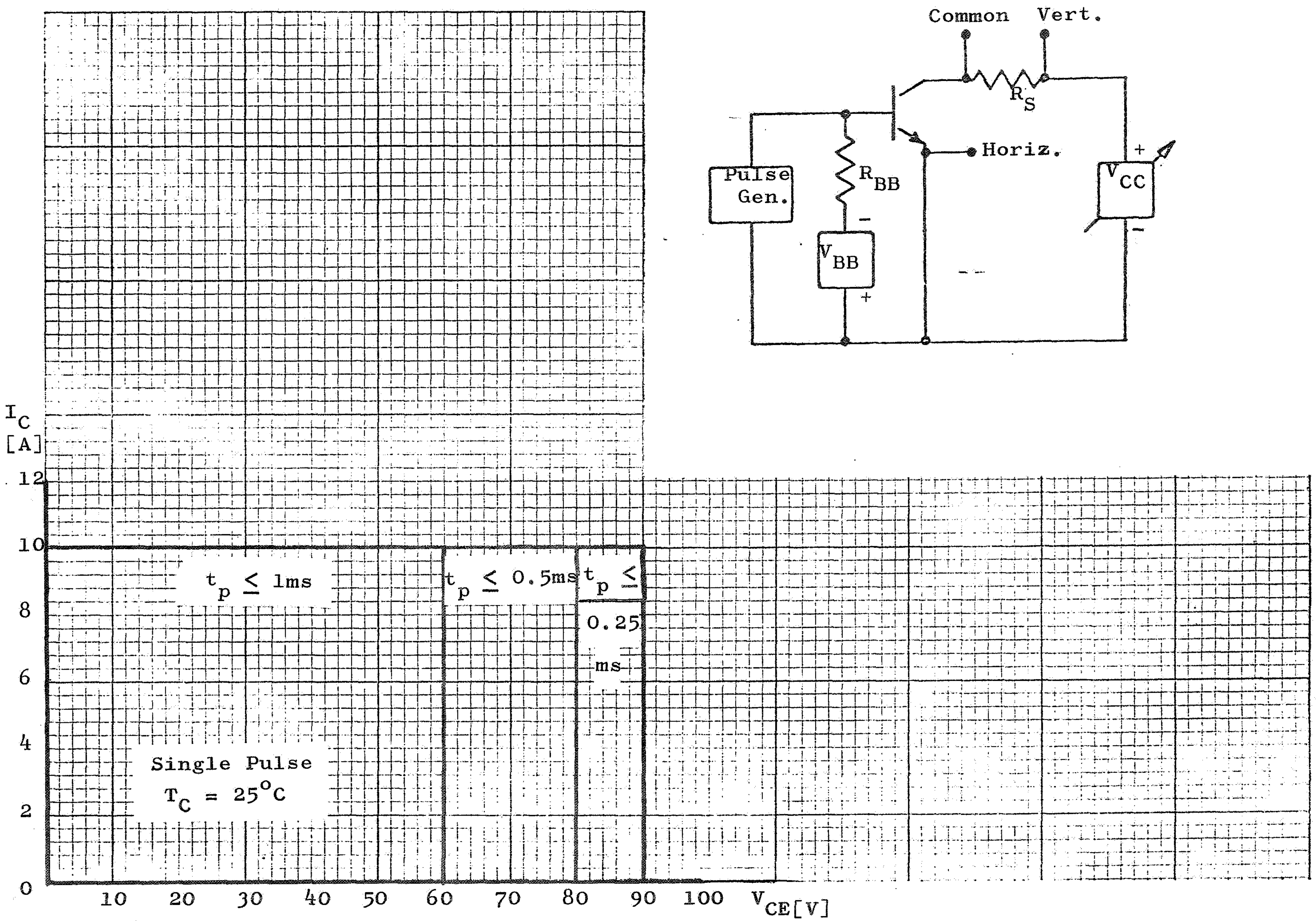
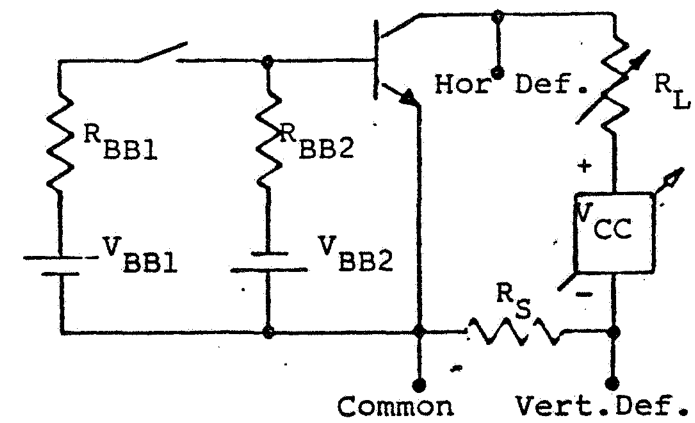
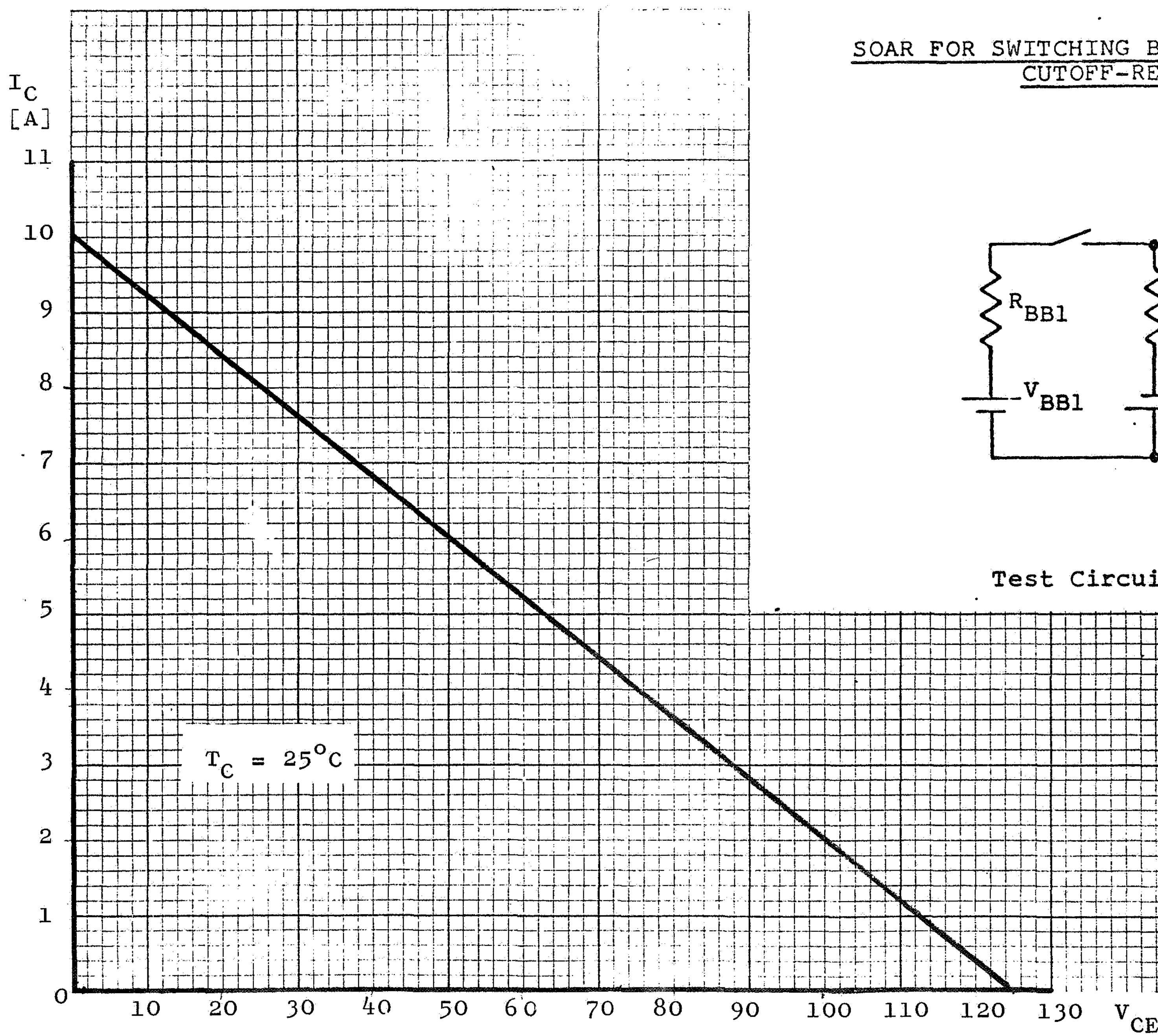


Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD



Test Circuit: JS-6-T5.2.1



SOAR FOR SWITCHING BETWEEN SATURATION & CUTOFF - CLAMPED INDUCTIVE LOAD

Test Circuit JS-6-T5.1

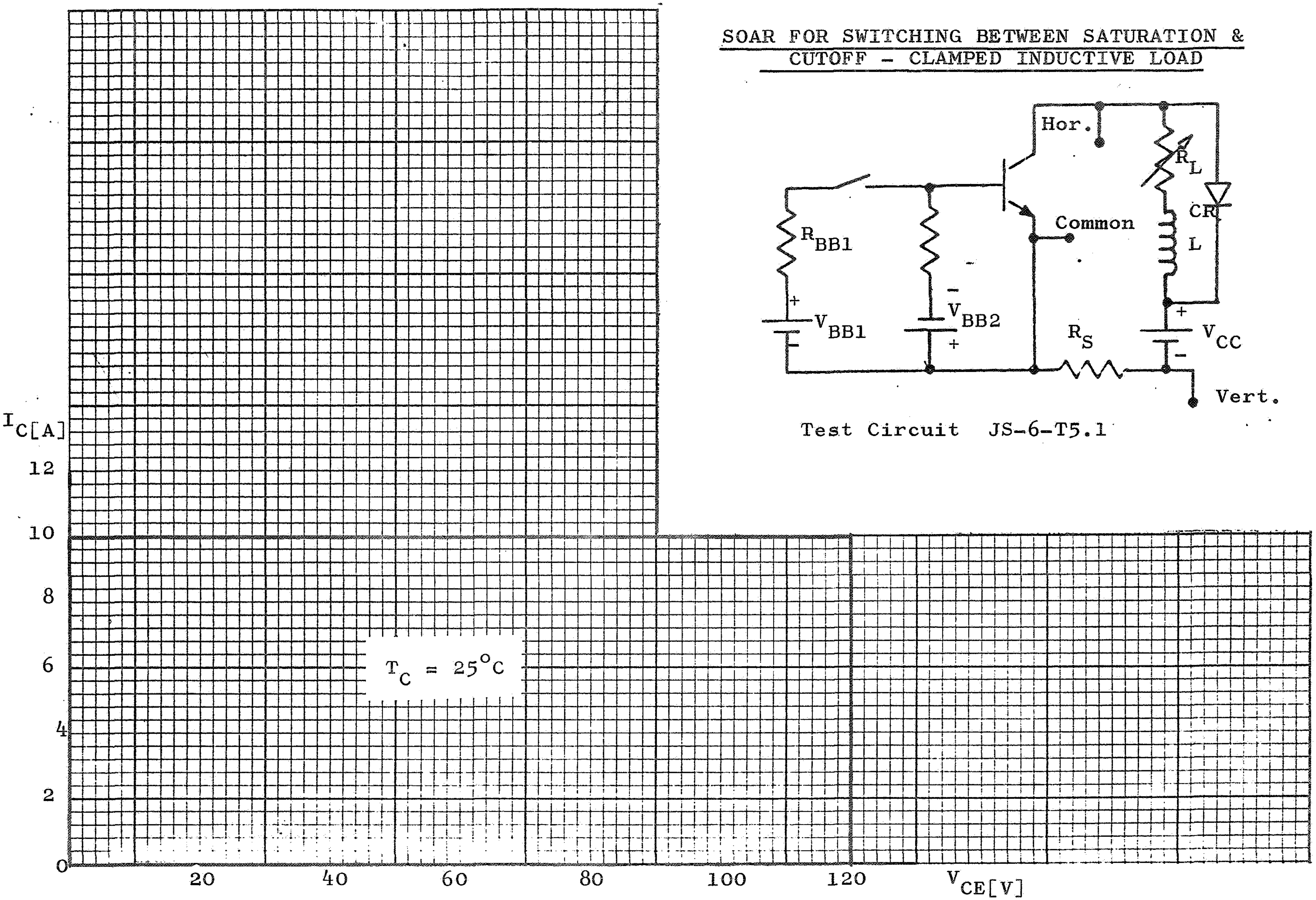
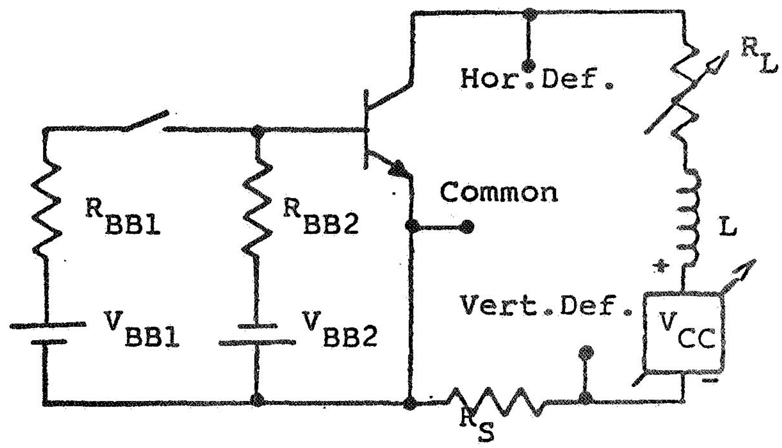
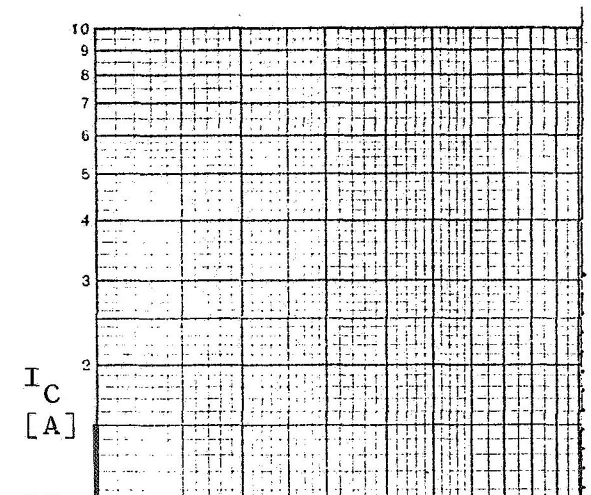


Figure 4



Test Circuit: JS-6-T5-2.1



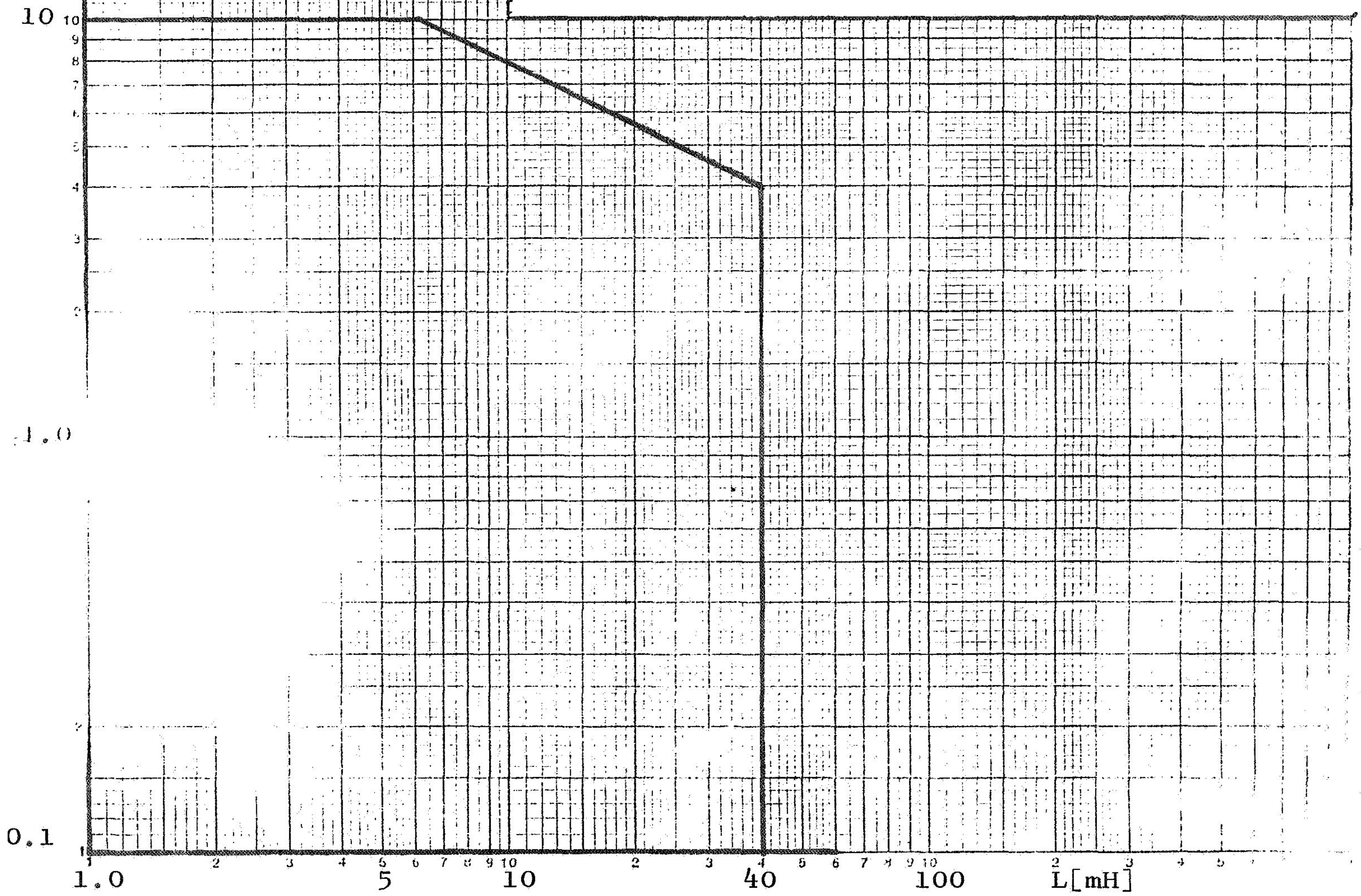


Figure 5

SWITCHING TEST CIRCUIT

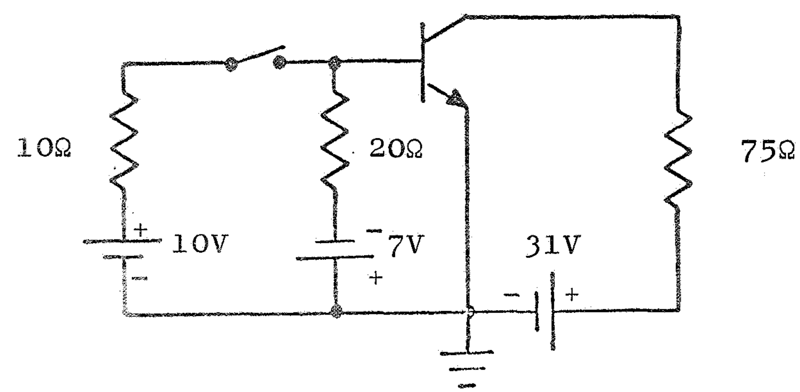


Figure 6

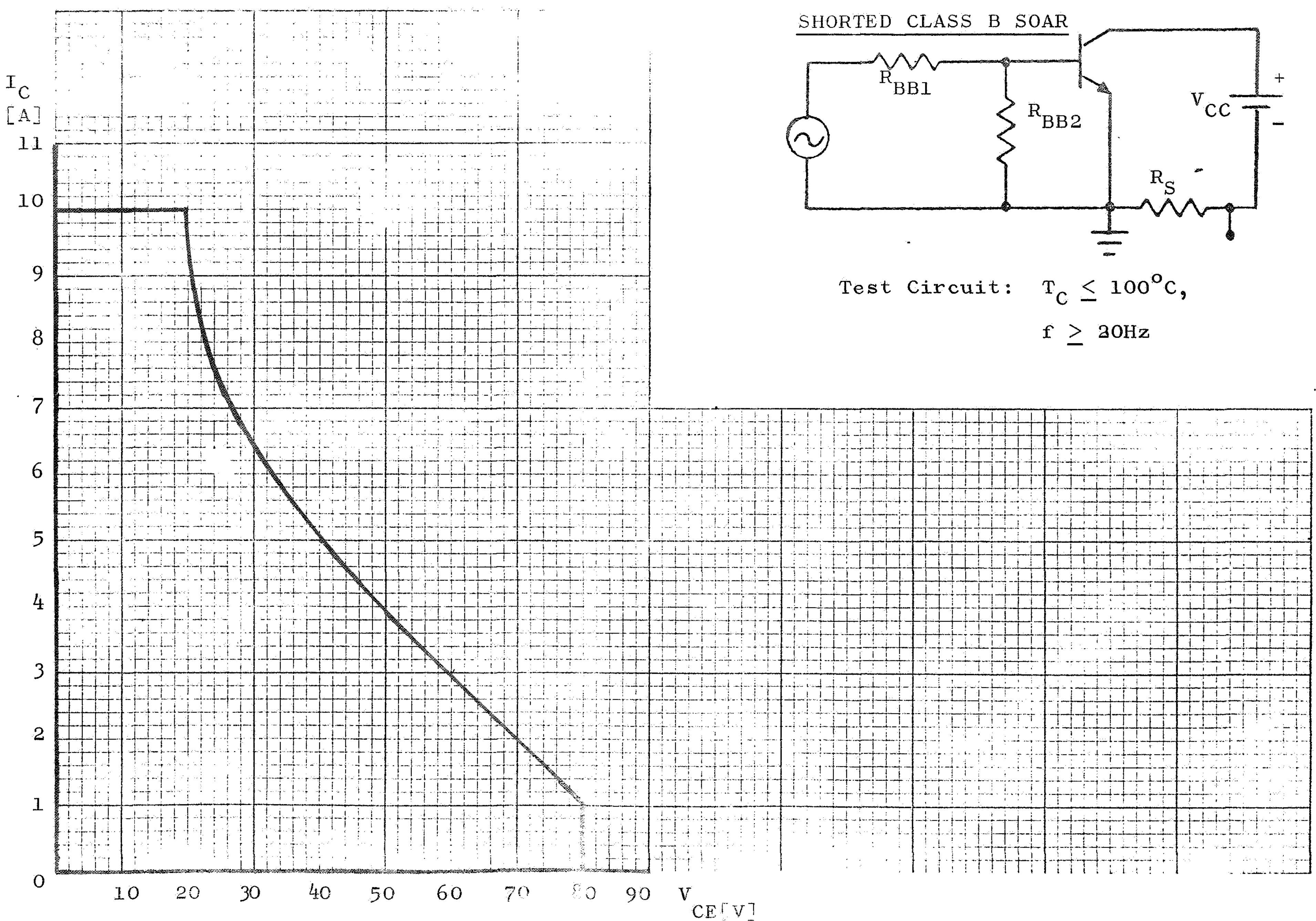

SHORTED CLASS B SOAR
R_{BB1}
R_{BB2}
V_{CC}
R_S
+
−
Test Circuit: $T_C \leq 100^oC$,
$f \geq 20Hz$
I_C [A]
11
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
60
70
80
90
V_{CE} [V]

Figure 7

-- TEST REPORT --

SILICON POWER TRANSISTOR

< 2N5560 >

SAFE OPERATING AREA
DETERMINATION FRO PREVENTION
OF SECOND BREAKDOWN

-- Manufacturer Bendix --

Performed for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

Contract Number NAS8-21155

The format used in the presentation of this data was recently developed for the registration of transistor specifications.

THE BENDIX CORPORATION
SEMICONDUCTOR DIVISION
HOLMDEL, NEW JERSEY

Item	Registered Data		Test Methods & Test Conditions	Remarks
1.0.0	GENERAL DESCRIPTION			**Triode Transistor Power Switching**
1.1.0	Type	NPN		NPN, PNP, etc.
1.2.0	Material	Silicon		Ge., Si., etc.
2.0.0	MECHANICAL DATA			Note 1
2.1.0	Outline	TO-63		Note 2
2.2.0	Terminal Designation			Indicate all unconnected terminals as "NC".
	1	Emitter		
	2	Base		
	3	Collector		
	case	Collector		Indicate "I" if all leads insulated from case.
3.0.0	MAXIMUM RATINGS			Note 3
3.1.0	Temperature			
3.1.1	T_{stg} (max)	200 °C	JS-6-T1.2	Test Methods JS-6-T___ See "Test Procedures for Verification of Maximum Ratings of Power Transistors" JEDEC Publication No.65
	T_{stg} (min)	-65 °C	JS-6-T1.1	
3.1.2	$T_{J(max)}$	200 °C	JS-6-T2	
			T_C 150 °C P_T = 75W	T_C = 75% to 90% T_J Max
			V_{CB} ≈ 4 V I_C 15 A	
3.1.3	T (Lead)	230 °C	Distance from case 1/16 in.	Item 3.1.3 is not required on transistors whose storage temperature is sufficiently high so that the lead temperature test becomes redundant.
			Time 10 s	

17653: 4a-10

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.2.0	Voltage	$T_C = 25°C$	
3.2.1	V_{CBO} 175 V	JS-6-T3	
3.2.2	V_{EBO} 8 V	JS-6-T4	
3.2.3	V_{CEX} 120 V	JS-6-T5.1	Inductive Method
		I_C ($V_{CE} = V_{CEX}$) 30 A	R_{BB2} may be infinite
		V_{CC} 120 V R_L 3.8 Ω	V_{BB2} may be zero
		L 1 mH CR 1N1202	Equivalent registered type number of CR, if used, must be given.
		V_{BB1} 12.2 V R_{BB1} 3 Ω	
		V_{BB2} 6 V R_{BB2} 20 Ω	
		Pulse Width 1 ms Duty Cycle 2 %	
	or	or	
		JS-6-T5.2	Pulsed Method
	V	I_C A R_{BB} Ω	R_{BB} may be zero
		$V_{BB(off)}$ V	
		Pulse Width ms Duty Cycle %	

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.3.0	Current		
3.3.1	I_C [30 A]	JS-6-T6 I_B [3 A] T_C [$\leq$ 25 °C]	Continuous collector current
3.3.2	I_{CM} [A]	JS-6-T7 T_C = 25°C R_S [Ω] V_{BB} [V] R_{BB} [Ω] Input Pulse Characteristics Pulse Amplitude [V] Pulse Width [ms] Duty Cycle [%] t_r [$\leq$ µs] t_f [$\leq$ µs]	Peak collector current
3.3.3	I_B [10 A]	JS-6-T8 T_C [$\leq$ 25 °C]	Continuous base current
3.3.4	I_{BM} [A]	JS-6-T9 T_C = 25°C Input Pulse Characteristics Pulse Width [ms] Duty Cycle [%] t_r [$\leq$ µs] t_f [$\leq$ µs]	Peak base current
3.3.5	I_E [33 A]	JS-6-T10 I_B [3 A] T_C [25 °C]	Continuous Emitter current

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.3.6	I_{EM} [A]	JS-6-T11 T_C= 25°C R_S [Ω] V_{BB} [V] R_{BB} [Ω] Input Pulse Characteristics Pulse Width [ms] Duty Cycle [%] t_r [≤ μs] t_f [≤ μs]	Peak Emitter Current
3.4.0	Power		
3.4.1	P_T 150 W	JS-6-T12 T_C 100 °C V_{CB} 4 V I_C 30 A	T_C= 55°C (for device with T_J (max) ≤ 125°C
	Derating Factor 1.5 W/°C		T_C= 100°C (for devices with T_J (max) > 125°C
3.4.2	P_{TM} 3600 W	JS-6-T13 T_C= 25°C V_{CC} 120 V V_{BB} 6 V R_{BB} 20 Ω Input Pulse Characteristics Pulse Width 0.125 ms Duty Cycle 0.4 % t_r ≤ 5 μs t_f ≤ 5 μs	$P_{TM} = I_C \; V_{CC}$

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.5.0	Maximum Operating Conditions		Refer to Appendix A
3.5.1	DC - Attach drawing of operating area V_{CE} vs I_C	T_C [100 °C] Fig. 1 1. I_C = 130 mA; V_{CE} = 120V 2. I_C = 450 mA; V_{CE} = 60V	T_C = T_C (3.4.1) The circuit of JS-6-T12 is recommended.
3.5.2	Pulsed (Forward Bias Drive) Attach drawing of operating area. V_{CE} vs I_C for one or more pulse widths	JS-6-T14 ; Fig. 2 T_C = 25°C V_{BB} [6 V] R_{BB} [20 Ω] Input Pulse Characteristics Pulse Width [____ ms] Duty Cycle [0.4 %] t_r [≦ 5 μs] [≦ 5 μs]	Pulse width shall be 1,2,3, or 5 x 10^x sec. Pulse Width [ms] / V_{CC} [V] / I_C [A] 1. 5 @ 30 / 30 2. 1 @ 50 / 30 3. 0.5 @ 75 / 30 4. 0.125 @ 120 / 30
3.6.0	Maximum Operating Conditions for Switching between Saturation and Cutoff		For example refer to Appendix B Specify 3.6.1 or 3.6.2 or 3.6.3
3.6.1	Resistive Load OR	JS-6-T5.1 with L = 0 and CR disconnected ; Fig. 3 T_C = [25 °C] Input Pulse Characteristics Pulse Width [1 ms] Duty Cycle [2 %] t_r [≦ 5 μs] t_f [≦ 5 μs] R_{BB1} [3 Ω] R_{BB2} [20 Ω] V_{BB1} [12.2 V] V_{BB2} [6 V]	Supply graph of Safe Operating Area on the I_C - V_{CE} plane. Safe Operating Area graph must include: V_{CE} (3.2.3) = 120V I_C (3.3.1) = 30A If one test condition cannot satisfy V_{CE} (3.2.3) and I_C (3.3.1) specify conditions for each test.

Item	Registered Data	Test Methods & Test Conditions	Remarks
3.6.2	Clamped Inductive Load OR	JS-6-T5.1 ; Fig. 4 T_C = 25 °C Input Pulse Characteristics Pulse Width 2 ms Duty Cycle 2 % t_r ≦ 5 µs t_f ≦ 5 µs R_{BB1} 3 Ω R_{BB2} 20 Ω V_{BB1} 12.2 V V_{BB2} 6 V L 1 mH CR 1N1202 The/JEDEC Type Number of the characteristics must be specified.	Supply graph of Safe Operating Area on the I_C-V_{CE} plane. Safe Operating Area graph must include: V_{CE} (3.2.3) = 120V I_C (3.3.1) = 30A If one test condition cannot satisfy V_{CE} (3.2.3) and I_C (3.3.1) specify conditions for each test.
3.6.3	Unclamped Inductive Load	JS-6-T5.1 and CR Disconnected T_C = 25 °C ; Fig. 5 Input Pulse Characteristics Pulse Width 5 ms Duty Cycle 5 % t_r ≦ 5 µs t_f ≦ 5 µs R_{BB1} 3 Ω R_{BB2} 20 Ω V_{BB1} 12.2 V V_{BB2} 6 V L 10 mH Q of L ≧ 1500 f_{RESON} of L ≧9.5 MHz I_C 1.4 A V_{CC} 36 V	For L = 0.1 mH; I_C = 30A I_C ≧ I_C (4.1.7)

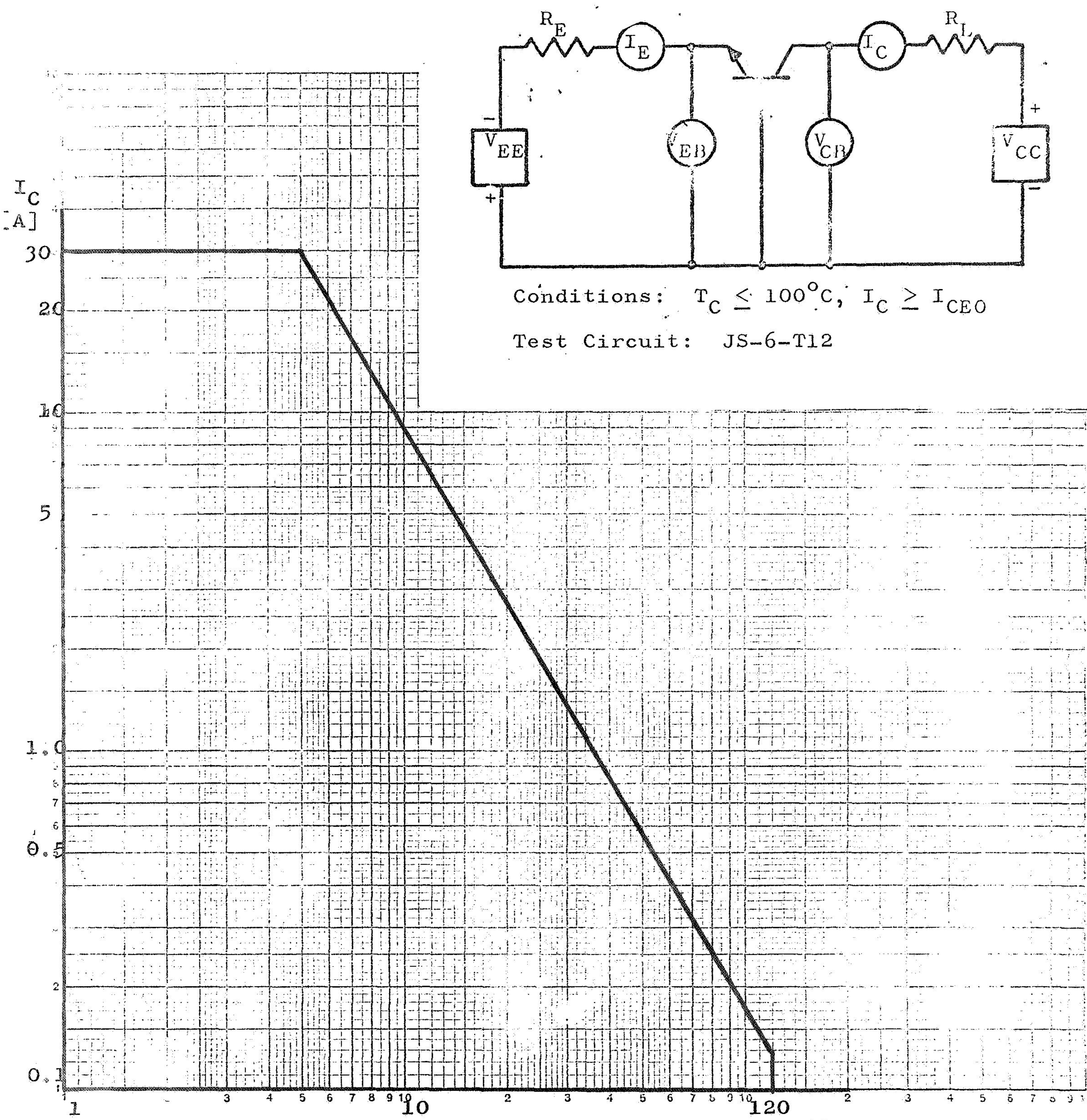
Item	Registered Data	Test Methods & Test Conditions	Remarks
4.0.0	Electrical Characteristics	T_C = 25°C (unless otherwise noted)	Maximum limits unless otherwise noted.
4.1.0	Static		Note 4
4.1.1	I_{CEV} 0.100 mA	T_C 125 °C V_{CE} 100 V	$T_C \geq 1/2\ T_J$ (3.1.2)
		V_{BE} (fwd., rev.) 0 V	
		Technique C.T.	
4.1.2	I_{CEV} 1.0 mA	V_{CE} 175 V	$V_{CE} \geq 0.9\ V_{CBO}$ (3.2.1) Specify 4.1.2 or 4.1.3 and 4.1.4
		V_{BE} (fwd., rev.) 0 V	
		Technique C.T.	
	or	or	
4.1.3	I_{CBO} mA	V_{CB} V	$V_{CB} = V_{CBO}$ (3.2.1)
	and	and	
4.1.4	V_{EBF} V	V_{CB} V	$V_{CB} = V_{CBO}$ (3.2.1)
		Technique	

Item	Registered Data	Test Methods & Test Conditions	Remarks
4.1.5	I_{EBO} 0.010 mA	V_{EB} 8 V Technique C.T.	$V_{EB} = V_{EBO}$ (3.2.2)
4.1.6	$V_{(BR)CEO}$ 120 Min V	I_C 25 mA I_B 0 mA Technique C.T.	Note 5
4.1.7	h_{FE} 30 Min 90 Max	V_{CE} 2 V I_C 15 A Technique C.T.	$V_{CE} \leq$ 2.0V or 2 x $V_{CE(sat)}$ (4.1.8) whichever is greater
4.1.8	$V_{CE(sat)}$ 0.8 Max V	I_C 15 A I_B 1.5 A Technique C.T.	$I_C = I_C$ (4.1.7) Measured 5/16" from case.
4.1.9	$V_{BE(sat)}$ 1.3 Max V	I_C 15 A I_B 1.5 A Technique C.T.	$I_C = I_C$ (4.1.7)
4.2.0	Dynamic		
4.2.1	t_r µs	V_{CC} I_C I_{B1}	Specify 4.2.1, 4.2.2 and 4.2.3 or 4.2.4 and 4.2.5 $I_C = I_C$ (4.1.7) Switching circuit shall be attached. $I_{B1} = I_B$ (4.1.8)
4.2.2	t_s µs	V_{CC} I_C I_{B1} I_{B2}	$I_C = I_C$ (4.1.7) $I_{B1} = I_B$ (4.1.8)
4.2.3	t_f µs	V_{CC} I_C I_{B1} I_{B2}	$I_C = I_C$ (4.1.7) $I_{B1} = I_B$ (4.1.8)
	or		

Item	Registered Data		Test Methods & Test Conditions	Remarks
4.2.4	t_{on}	1.0 μs	V_{CC} 31 V I_C ≈ 15A	$I_C = I_C$ (4.1.7)
		and	I_{B1} ≈1.5 A Fig. 6	$I_{B1} = I_B$ (4.1.8)
4.2.5	t_{off}	2.0 μs	V_{CC} 31 V I_C 15 A	$I_C = I_C$ (4.1.7)
			I_{B1} ≈ 1.5 A I_{B2} ≈1.5 A	$I_{B1} = I_B$ (4.1.8)
4.2.6	f_{hfe}	kHz	I_C A V_{CE} V	Specify 4.2.6 or 4.2.7
		or		
4.2.7	$\|h_{fe}\|$	8 min 20 max	V_{CE} 10 V I_C 1 A	Specify 4.2.6 or 4.2.7
			5 MHz	Note 6

Item	Registered Data	Test Methods & Test Conditions	Remarks
	<u>ADDITIONAL DATA</u>		
3.6.4	Shorted Class B Safe Operating Area	Fig. 7 $R_S = 0.1\Omega$ 1. $I_C = 1.1A$; $V_{CC} = 60V$ 2. $I_C = 390$ mA; $V_{CC} = 120V$ Input Characteristics $R_{BB1} = 1\Omega$; $R_{BB2} = 3\Omega$ $f = 20$ Hz; $T_C = 100^{\circ}C$	
3.6.5	$P_T = 40W$	JS-6-T12; $V_{CE} = 60$; $I_C = 0.66A$ $t_p = 1s$; $T_A = 25^{\circ}C$	
4.1.10	$I_{CEO} = 25\ \mu A$ max.	$V_{CE} = 80V$ Technique C.T.	
4.1.11	$V_{CES} = 125V$ min.	$I_C = 10$ mA; $R_{CC} = 500\Omega$ Technique C.T.	
4.1.12	$V_{EBO} = 8V$ min	$I_E = 200$ mA; $R_{BB} = 500\Omega$ Technique C.T.	
4.1.13	$h_{FE} = 40$ min	$I_C = 0.1A$; $V_{CE} = 2V$ Technique C.T.	
4.1.14	$h_{FE} = 40$ min $h_{FE} = 100$ max	$I_C = 5A$; $V_{CE} = 1.5V$	
4.1.15	$h_{FE} = 10$ min	$I_C = 15A$; $V_{CE} = 2V$	After exposure level of $\phi = 1 \times 10^{13}$ nvt (Total integrated neutron flux with energy levels greater than 10 KeV)
4.1.16	$V_{CE(sat)} = 1.5V$ max	$I_C = 30A$; $I_B = 3A$; Technique C.T.	Measured 5/16" from case.
4.1.17	$V_{BE(sat)} = 2.0V$ max	$I_C = 30A$; $I_B = 3A$; Technique C.T.	
4.1.18	$C_{obo} = 600$ pF max.	$V_{CB} = 10V$; $f = 1$ MHz	
4.3.0	$\theta_{JC} = 0.67^{\circ}C/W$ max.	$I_C = 1A$; $V_{CE} = 20V$	
4.3.1	$\theta_{JA} = 30^{\circ}C/W$	$I_C = 1A$; $V_{CE} = 2V$	
4.3.2	$\tau_J = 25$ ms min.	$I_C = 1A$; $V_{CE} = 20V$	Time to reach 63% of equilibrium temperature for P_T step input.

FORWARD BIASED CONTINUOUS SOAR



Conditions: $T_C \leq 100^{\circ}C$, $I_C \geq I_{CEO}$

Test Circuit: JS-6-T12

Figure 1

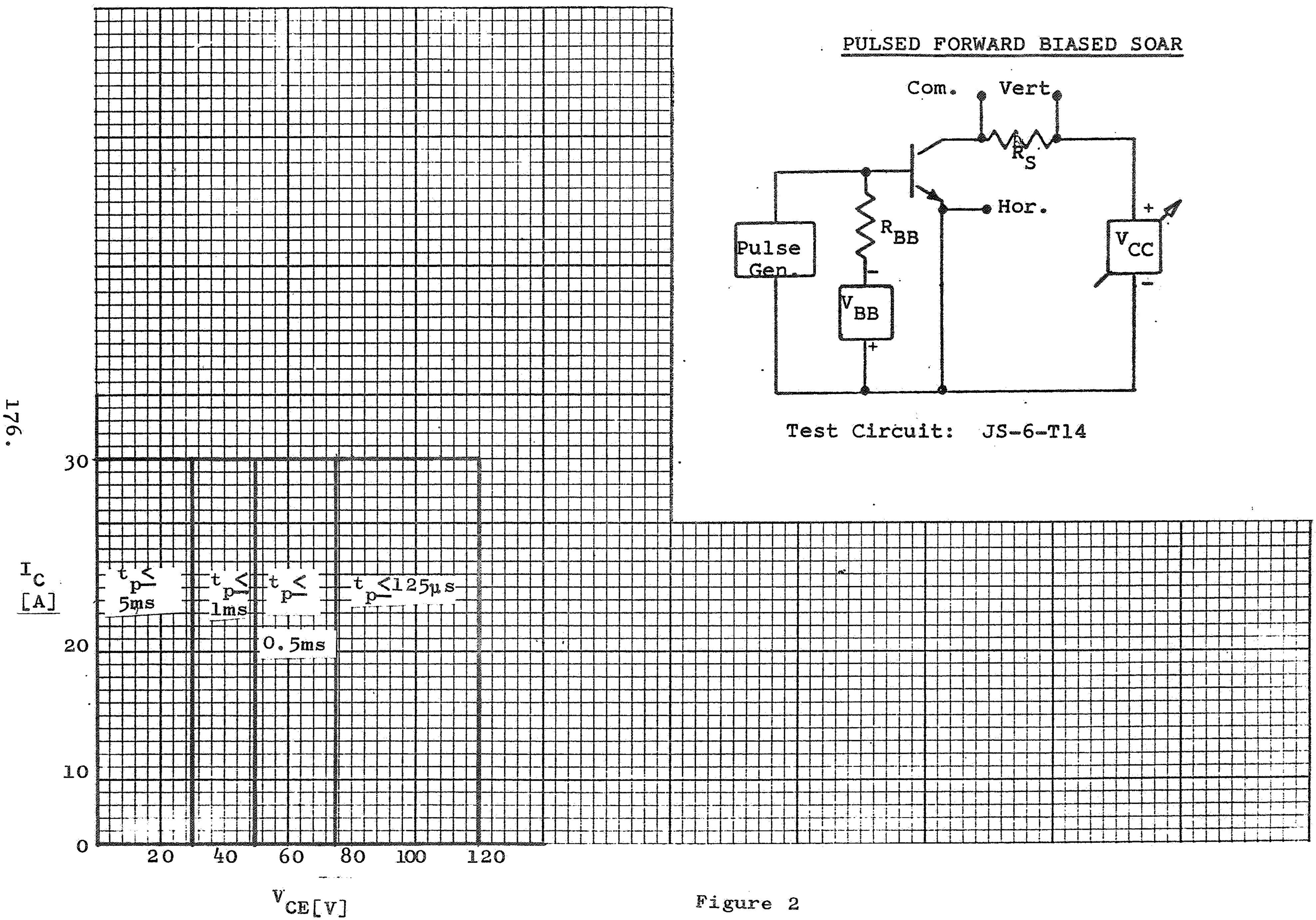

PULSED FORWARD BIASED SOAR
Com.
Vert.
R_S
Hor.
R_{BB}
Pulse Gen.
V_{BB}
V_{CC}
Test Circuit: JS-6-T14
I_C [A]
30
20
10
0
20
40
60
80
100
120
V_{CE}[V]
$t_p \leq$ 5ms
$t_p \leq$ 1ms
$t_p \leq$ 0.5ms
$t_p \leq 125\mu s$

Figure 2

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-RESISTIVE LOAD

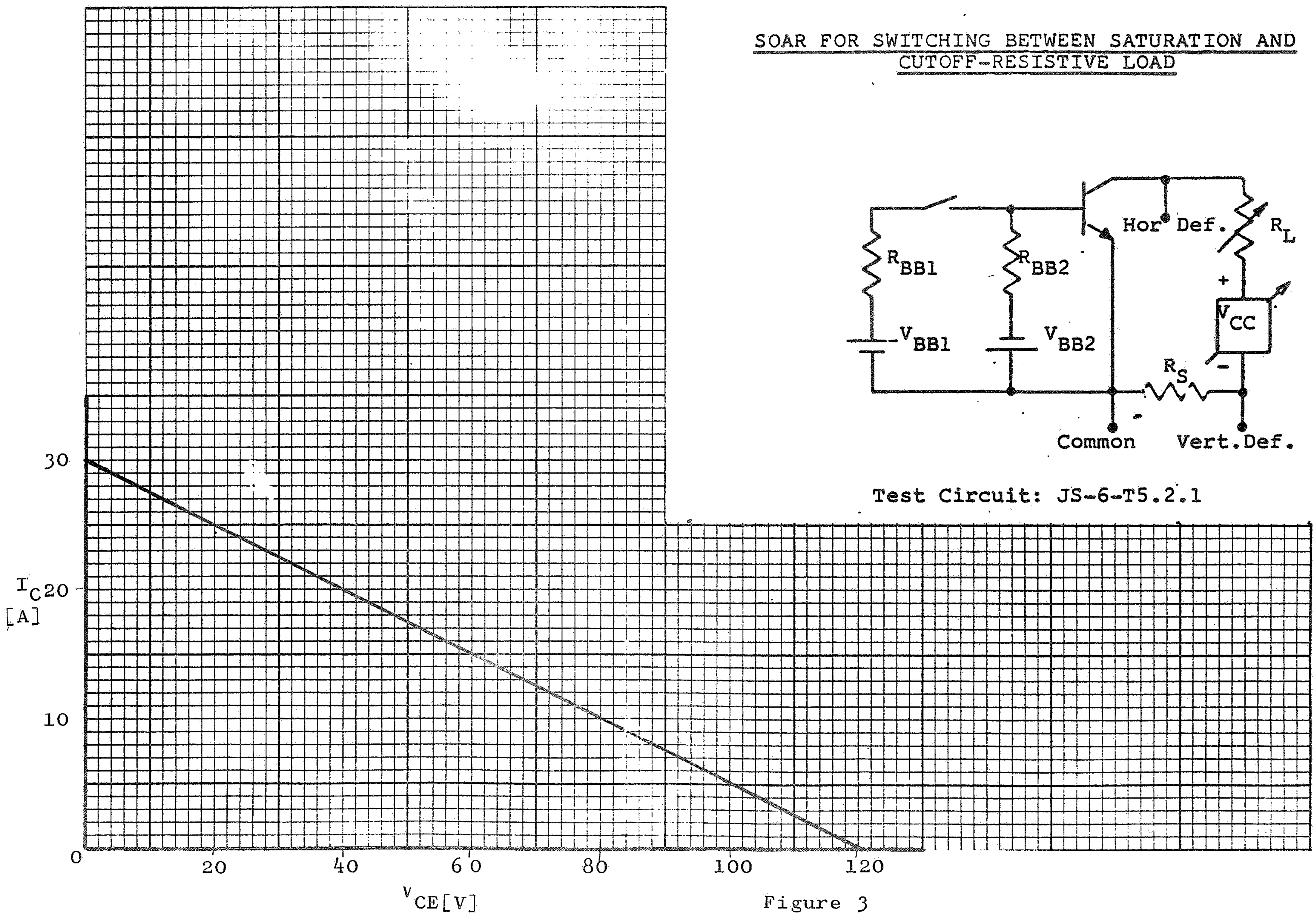
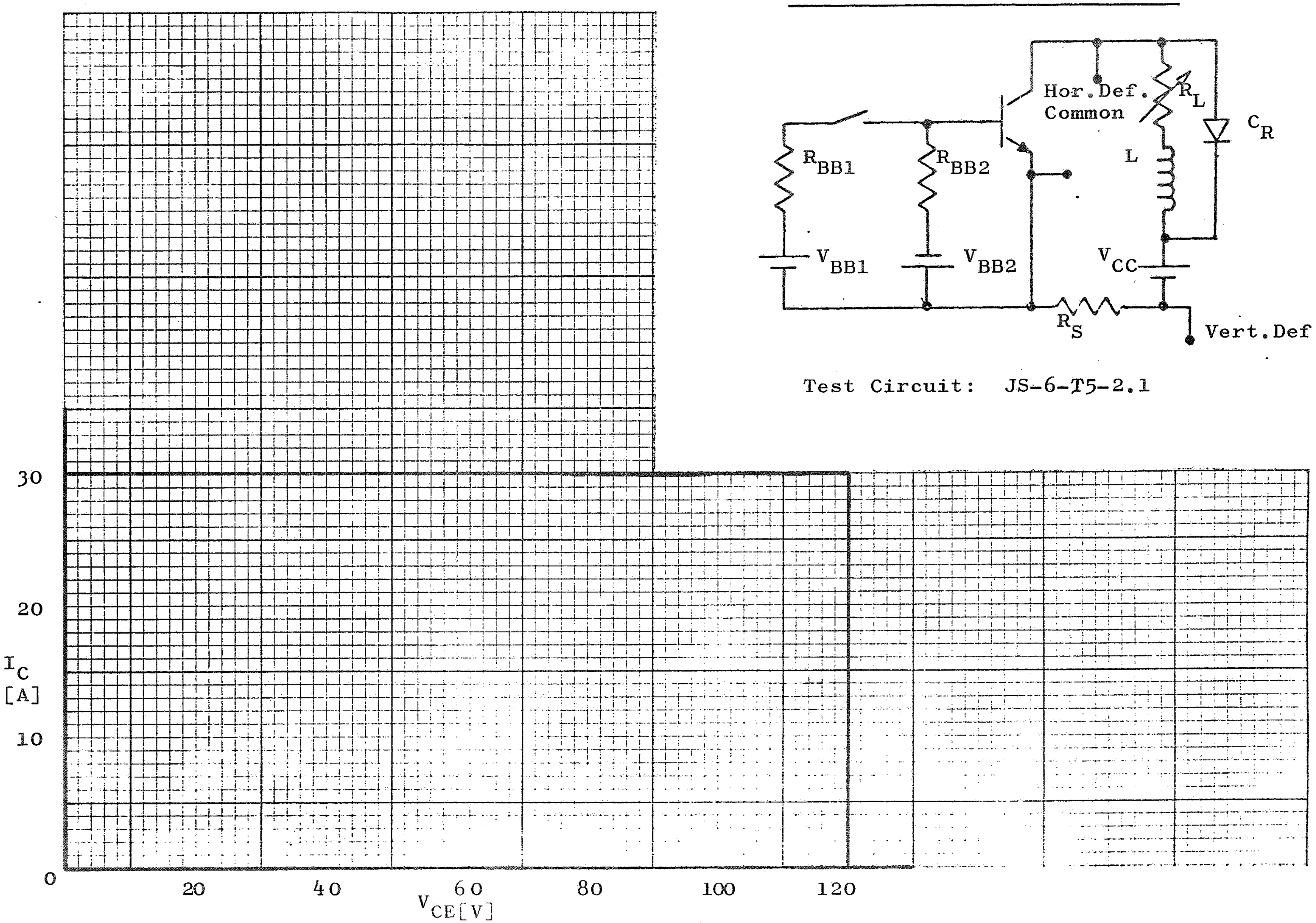


Figure 3

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-CLAMPED INDUCTIVE LOAD



Test Circuit: JS-6-T5-2.1

Figure 4

SOAR FOR SWITCHING BETWEEN SATURATION AND CUTOFF-UNCLAMPED INDUCTIVE LOAD

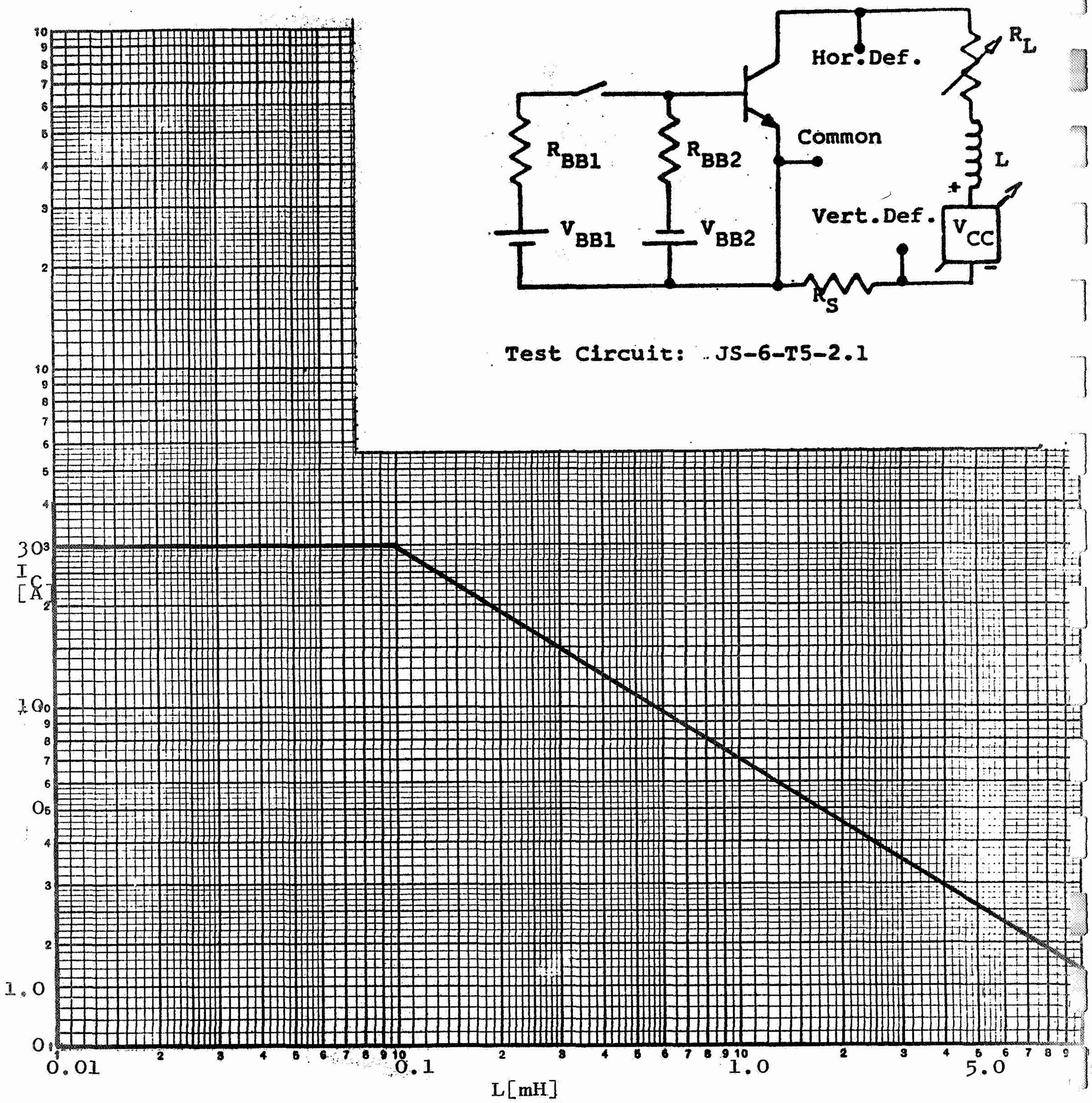
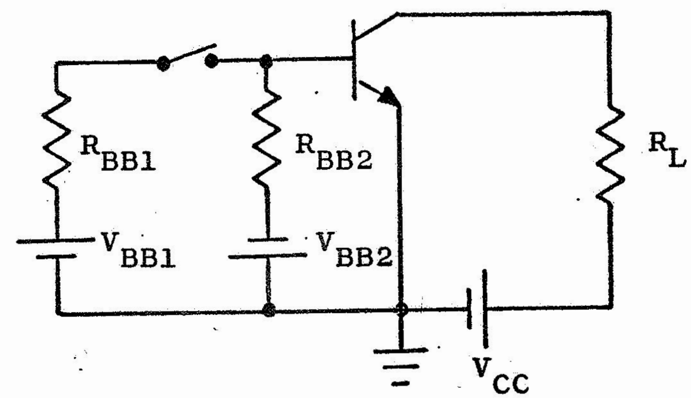


Figure 5

SWITCHING TEST CIRCUIT



Input Pulse: $t_r < 20ns$, $t_f < 20ns$, $t_p = 10\mu s$
Duty Cycle = 1%
$R_{BB1} = 3\Omega$, $V_{BB1} = 11.2V$
$R_{BB2} = 4\Omega$, $V_{BB1} = 6V$
$R_L = 2\Omega$, $V_{CC} = 31V$

Figure 6

SHORTED CLASS B SOAR

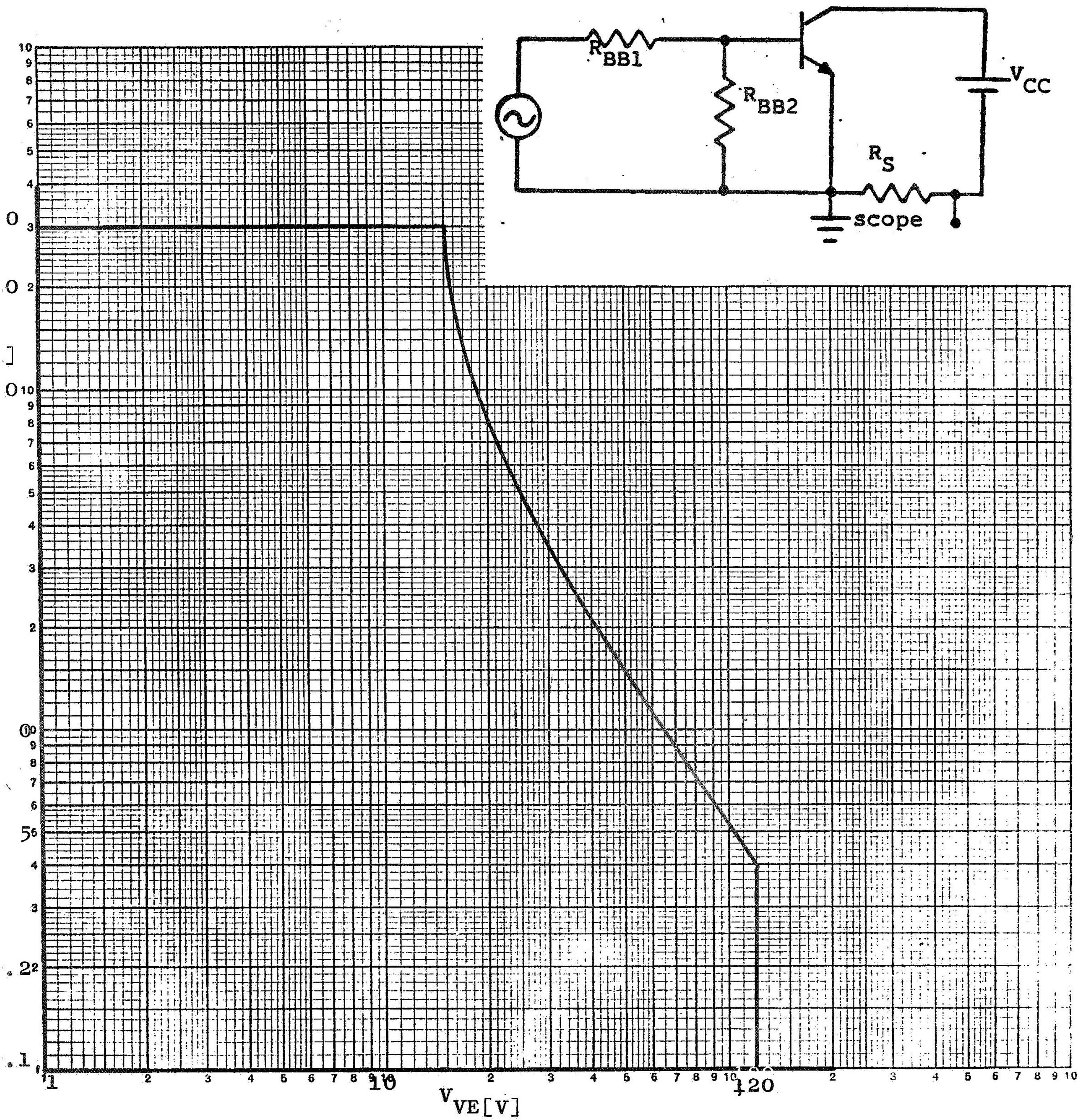


Figure 7

APPENDIX I

ADDENDUM

The reports in Sections 7 and 11 contain the results obtained from two groups of the same type of transistor from two different manufacturers.

This type of testing yielded a better device variation which indicates that wide differences do exist between manufacturers and approved products.

From the data obtained from both groups of devices a single SOAR specification was generated. The combined results expand the JEDEC registration and supplements the specification with complete SOAR curves and test conditions.

Although the test limits encompass both manufacturers devices, some manufacturers may have to re-evaluate their devices at the specified SOAR points.